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THE OBJECTIVE OF THIS CMP IS TO: VERIFY AND EVALUATE POTENTIAL AIR QUALITY HEALTH HAZARDS, TO VERIFY PROGRESS THAT HAS BEEN MADE TO DATE IN REMOVING CONTAMINANTS RESULTING FROM PREVIOUS ACTIVITIES, TO PROVIDE BASELINE DATA FOR THE EVALUATION OF PROGRESS THAT WILL BE MADE IN FUTURE REMEDIAL ACTIVITIES, TO DEVELOP REAL-TIME GUIDELINES, STANDARD PROCEDURES AND DATA COLLECTION METHODS, AS APPROPRIATE, TO INDICATE IMPACTS OF ONGOING, REMEDIAL ACTIONS, AND TO VALIDATE AND DOCUMENT DATABASE RELIABILITY.

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COMPREHENSIVE MONITORING PROGRAM

Contract Number DAAA15-87-0095

AIR QUALITY DATA ASSESSMENT REPORT FOR FY90

FINAL REPORT

SEPTEMBER 1991

Version 3.1
Volume III

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Prepared for:

U. S. ARMY PROGRAM MANAGER FOR
ROCKY MOUNTAIN ARSENAL

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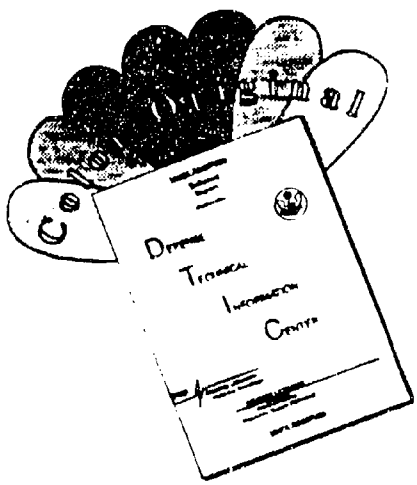

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

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LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

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LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

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ACRONYMS AND ABBREVIATIONS

111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
ADI	Acceptable Daily Intake
Atrazine	2-chloro-4-ethylamino-6-isopropylamino-s-trianine
BCHPD	Bicycloheptadiene
C_6H_6	Benzene
CCl_4	Carbon Tetrachloride
CH_2Cl_2	Methylene Chloride
$CHCl_3$	Chloroform
Chlordane	1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene
ClC_6H_5	Chlorobenzene
CMP FY90	Comprehensive Monitoring Program Fiscal Year 1990
CO	Carbon Monoxide
CRL	Certified Reporting Limit
DBCP	Dibromochloropropane
DCLE11	1,1-Dichloroethane
DCLE12	1,2-Dichloroethane
DCPD	Dicyclopentadiene
DDD	Dichlorodiphenyldichloroethane
DMB12	Dimethylbenzene
DMDS	Dimethyl Disulfide
EPA	Environmental Protection Agency
ETC_6H_5	Ethylbenzene
GC/MS	Gas Chromatography/Mass Spectrometry
GC/ECD	Gas Chromatography/Electron Capture Detection
ICAP	Inductively Coupled Argon Plasma
Malathion	0,0-dimethyl-s-(1,2-dicarboxyethyl) phosphorodithioate
MEC_6H_5	Toluene
MIBK	Methyl Isobutyl Ketone
MST	Mountain Standard Time
NAAQS	National Ambient Air Quality Standards
NATICH	National Air Toxics Information Clearinghouse
NIOSH	National Institute of Occupational Safety and Health
NNDMEA	N-Nitrosodimethylamine
NO_x	Nitrogen Oxides
O_3	Ozone

ACRONYMS AND ABBREVIATIONS (continued)

OCP	Organochlorine Pesticides
Parathion	Parathion ($C_{10}H_{14}NO_5PS$)
PMRMA	Program Manager, Rocky Mountain Arsenal
PM-10	Respirable Particulates less than 10 microns
PPDDE	Dichlorodiphenylethane
PPDDT	Dichlorodiphenyltrichloroethane
SO_2	Sulfur Dioxide
Supona	2-chloro-1-(2,4-dichlorophenyl) vinyl diethyl phosphate
SVOC	Semi-Volatile Organic Compounds
T12DCE	Trans-1,2-Dichloroethene
TCLEE	Tetrachloroethene
TLV	threshold limit value
tpy	tons per year
TRCLE	Trichloroethene
TSP	Total Suspended Particulates
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency
USAEHA	U.S. Army Environmental Hygiene Agency
VOC	Volatile Organic Compounds
XYLENE	Xylene

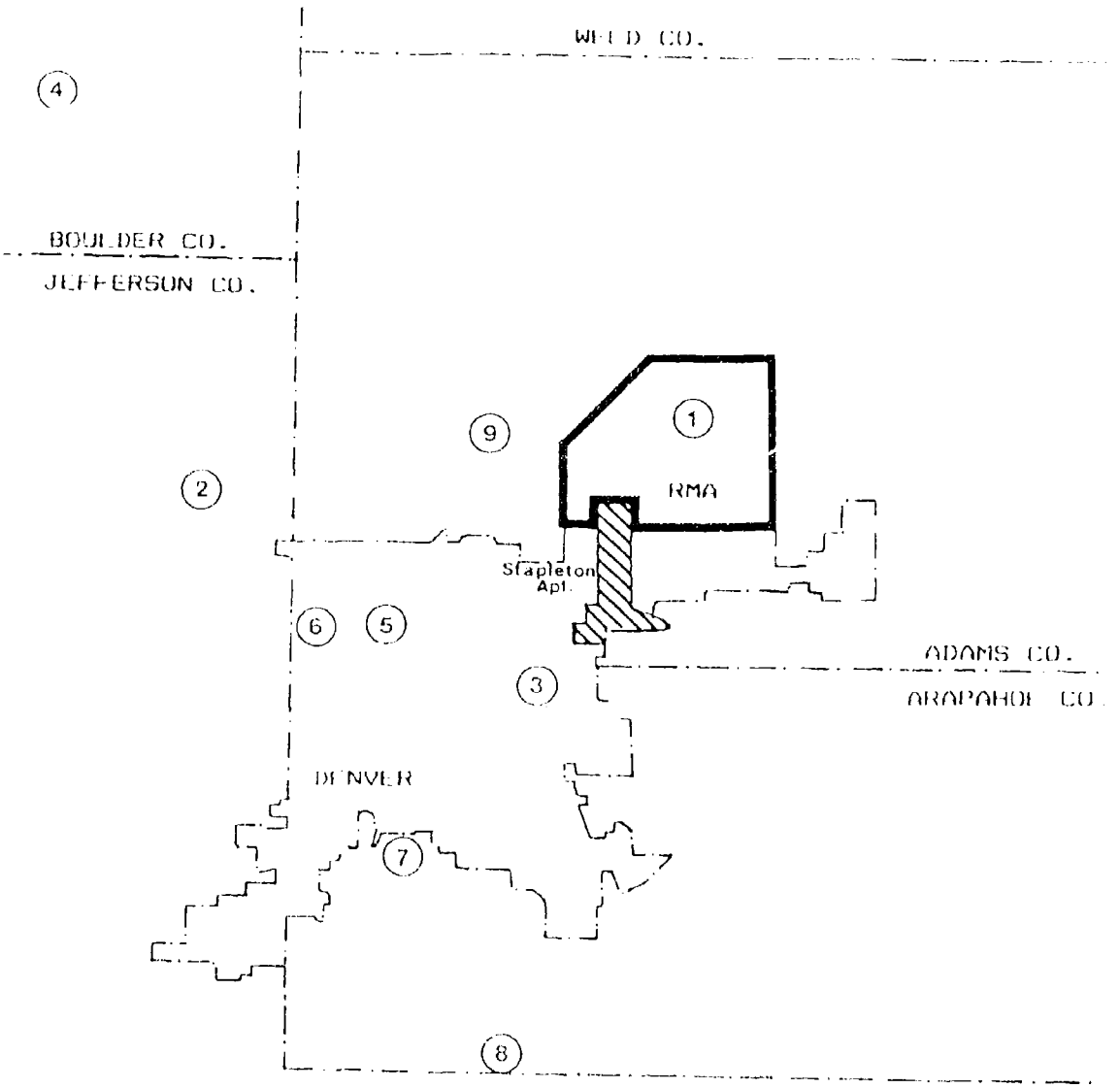
5.0 CONTINUOUS AIR MONITORING PROGRAM

5.1 PROGRAM OVERVIEW

The Continuous Air Monitoring Program is described in Section 3.6. Measurements of criteria gaseous pollutants were taken continuously, and recorded automatically in a data acquisition system. The hourly averages of the sampling data for carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2) and nitrogen oxides (NO_x) are presented in Appendix I for the period October 1, 1989, through September 30, 1990, and are summarized in this section. A description of the regional atmospheric characteristics of these gases is found in Sections 2.1.3 through 2.1.6.

The purpose of the gaseous monitoring program was to identify background concentrations of pollutants which play a role in possible future remediation activities. An assessment of these data yields additional insight into the atmospheric characteristics in and around the RMA site. It provides a general overview of the gaseous concentrations, as well as highlighting any anomalous values. The analysis also helps to identify meteorological and dispersion conditions which may effect air quality at RMA. For example, frequently occurring diurnal drainage wind pattern with a south to north air flow at night and a north to south air flow during the day affects all six gas concentrations to some extent. Diurnal drainage winds are described in more detail in Section 2.2. Daytime photochemical activity primarily influences O_3 and NO_2. A summary of average and 1-hour maximum concentrations as measured during the FY90 program, as well as additional analyses, is provided in this section.

A second major objective of the Continuous Air Monitoring Program was to compare the RMA concentrations with those of nearby regional continuous air monitoring sites. These adjacent sites are administrated by the Colorado Department of Health - Air Pollution Control Division (CDH). Locations of the CDH continuous air monitoring sampling sites are illustrated in Figure 5.1-1 and described in Table 5.1-1. Though there are several CDH monitoring sites located in and around the Denver metropolitan area, this report primarily compares the monitoring site at RMA to two of the CDH monitoring sites. These sites include the CAMP site located at 2105 Broadway in the downtown area of metropolitan Denver and the Welby site located at Seventy-eighth and Steele Street in Commerce City. These two sites were chosen because they generally represent the Denver metropolitan area and because the Welby site is relatively close in proximity to RMA and will be used for comparative representativeness to RMA.



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Commerce City, Colorado

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Figure 5.1-1

RMA and Colorado Department of Health Continuous Air Quality Monitoring Sites

CMP AR FY90

Table 5.1-1 RMA and Colorado Department of Health Gaseous Emissions Monitoring Sites

Site Number	Site Name	Site Address	Reported Parameters					
			CO	O3	SO2	NO	NO2	NOX
1	RMA	8th Avenue at D Street	X	X	X	X	X	X
2	Arvada	57th at Garrison						
3	Albion	14th at Albion						
4	Boulder	2320 Marine						
5	Camp	2105 Broadway	X	X	X		X	
6	Carriage	23rd and Julian	X	X				
7	Englewood	3300 South Huron	X	X				
8	Highland	8100 South University	X	X				
9	Welby	78th at Steele	X	X	X		X	

The Continuous Air Monitoring Program serves to establish baseline levels of gaseous constituents for future air quality assessments. Measured concentrations can be compared with various meteorological data such as wind direction and stability to identify possible migration patterns of gaseous pollutants from metropolitan Denver onto RMA. Also, baseline levels may be used to predict the impact a future remedial activity source may have on the environment. The results shown here represent a complete year of data collection and an assessment of diurnal and annual cycles of each gas.

5.2 Analysis Overview

A variety of tables and graphs were used to summarize the continuous air quality data. Mean values refer to daily averages and the 1-hour maximum value refers to the highest 1-hour average value recorded daily. Comparisons of RMA data were made with National Ambient Air Quality Standards (NAAQS) as well as with data from Colorado Department of Health sites. A further comparison was made for the data collection period of May through September for CMP FY89 and the current CMP FY90 data. The analyses for carbon monoxide, ozone, and sulfur dioxide are presented individually in the following subsections. For nitric oxide, nitrogen dioxide, and nitrogen oxides, a combined analyses is provided because of the similarities in their chemical composition and concentration characteristics. Case studies were presented to examine the possible sources of some of the higher concentrations observed at RMA.

5.3 Carbon Monoxide

The series of daily mean and 1-hour maximum carbon monoxide concentrations are illustrated in Figures 5.3-1a and 5.3-1b, respectively. During the sample collection period for FY90, there were a number of occasions where the daily maximum was several times greater than the daily average. Also for this period, there were several occasions where the daily maximum and the daily mean were nearly the same value. Such instances usually occurred when persistent winds were blowing with a northerly component or a southeasterly component. This flow allowed industrial pollutant matter to migrate away from RMA and thus not be detected.

Figures 5.3-1a and 5.3-1b depict the continuous annual cycle of CO values for RMA which is basically a reflection of the Denver metropolitan area. This cycle is also illustrated for mean monthly maximum and monthly mean values for the entire CMP FY89 and FY90 monitoring period from May 1989 to September 1990 in Figure 5.3-2. Evident in these graphs is the gradual increase in the daily mean, and mean monthly maximum and monthly mean concentrations during the fall and winter

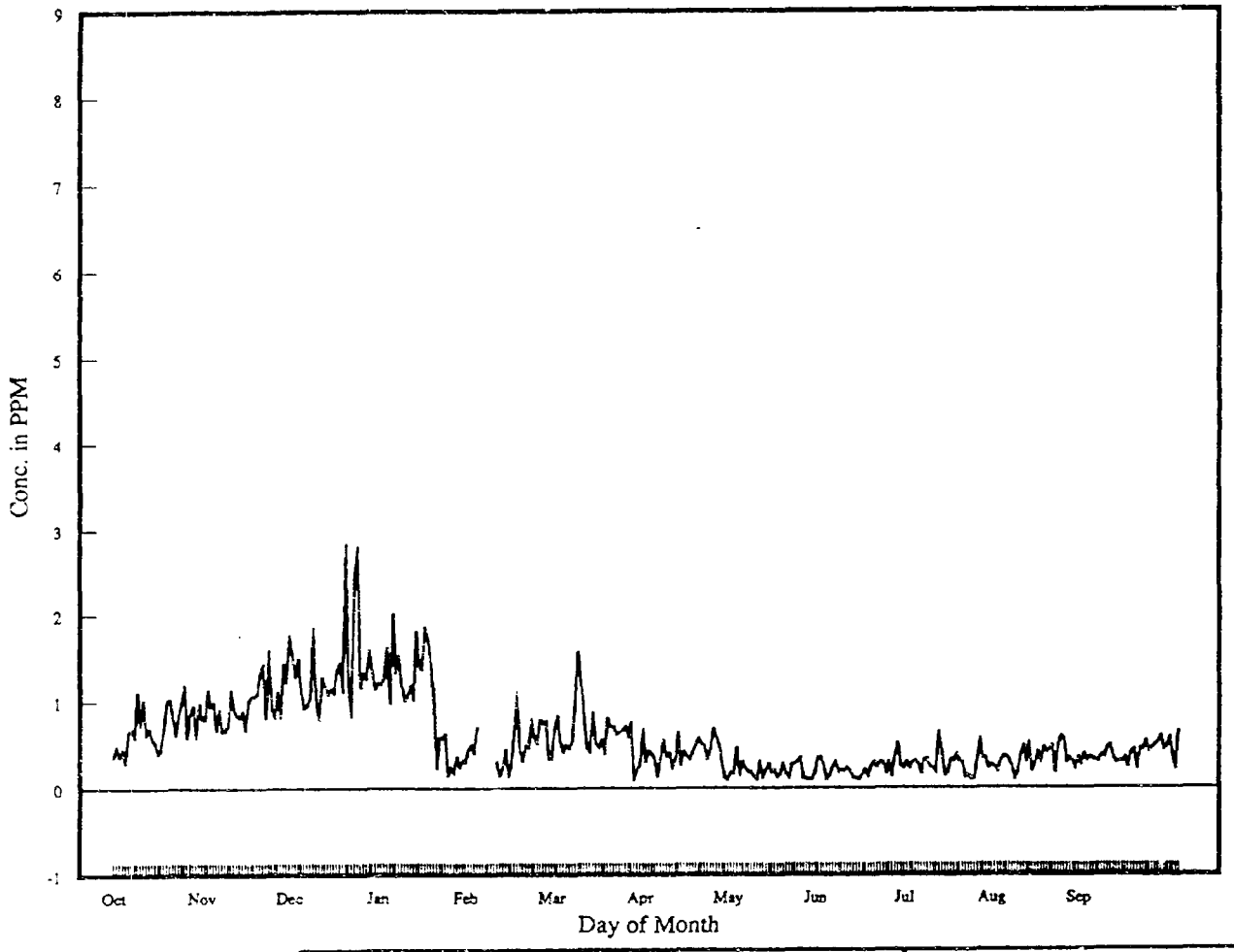

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Figure 5.3-1a

Graphical Depiction of Daily Mean for Carbon Monoxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

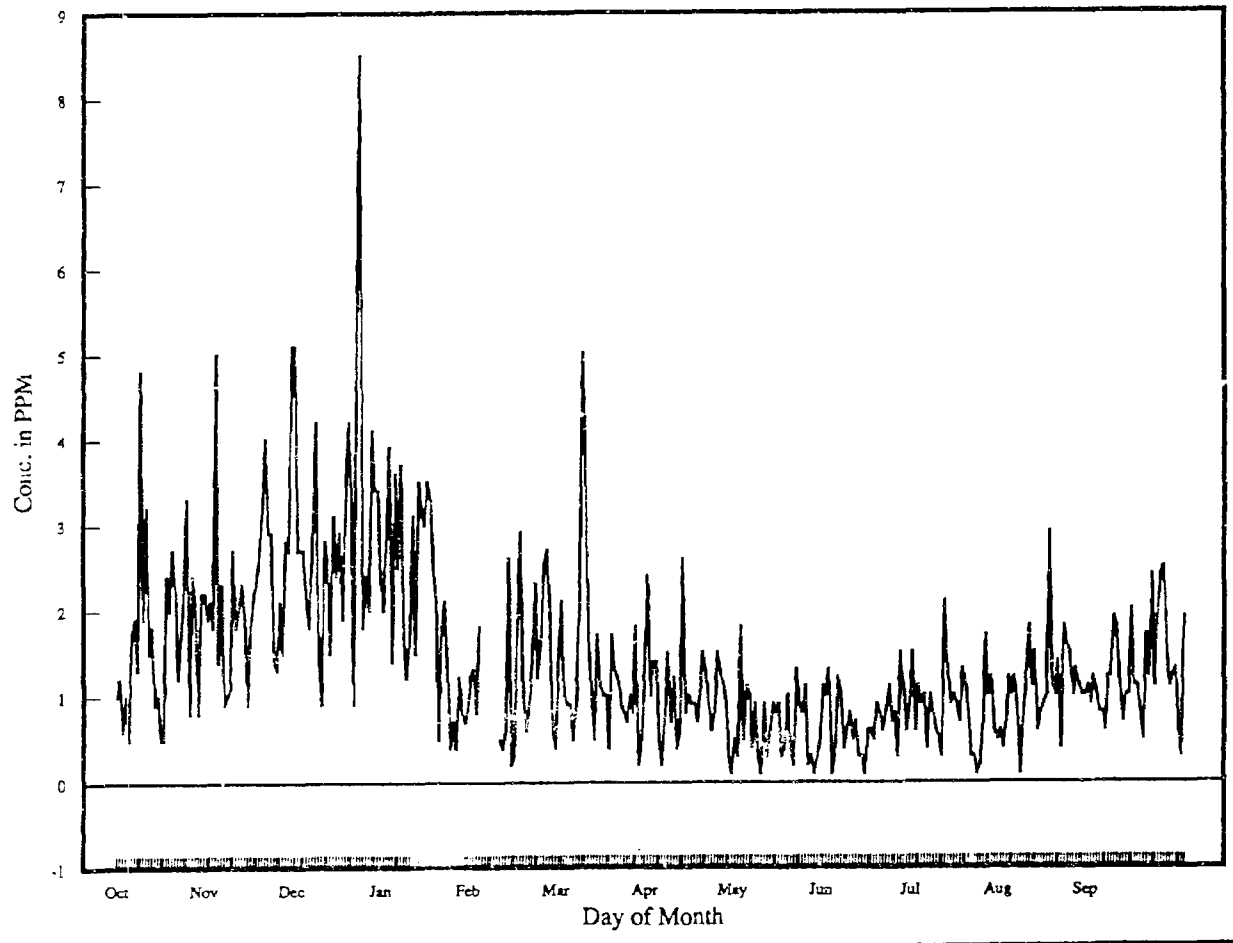

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Figure 5.3-1b

Graphical Depiction of Daily Maximum for Carbon Monoxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

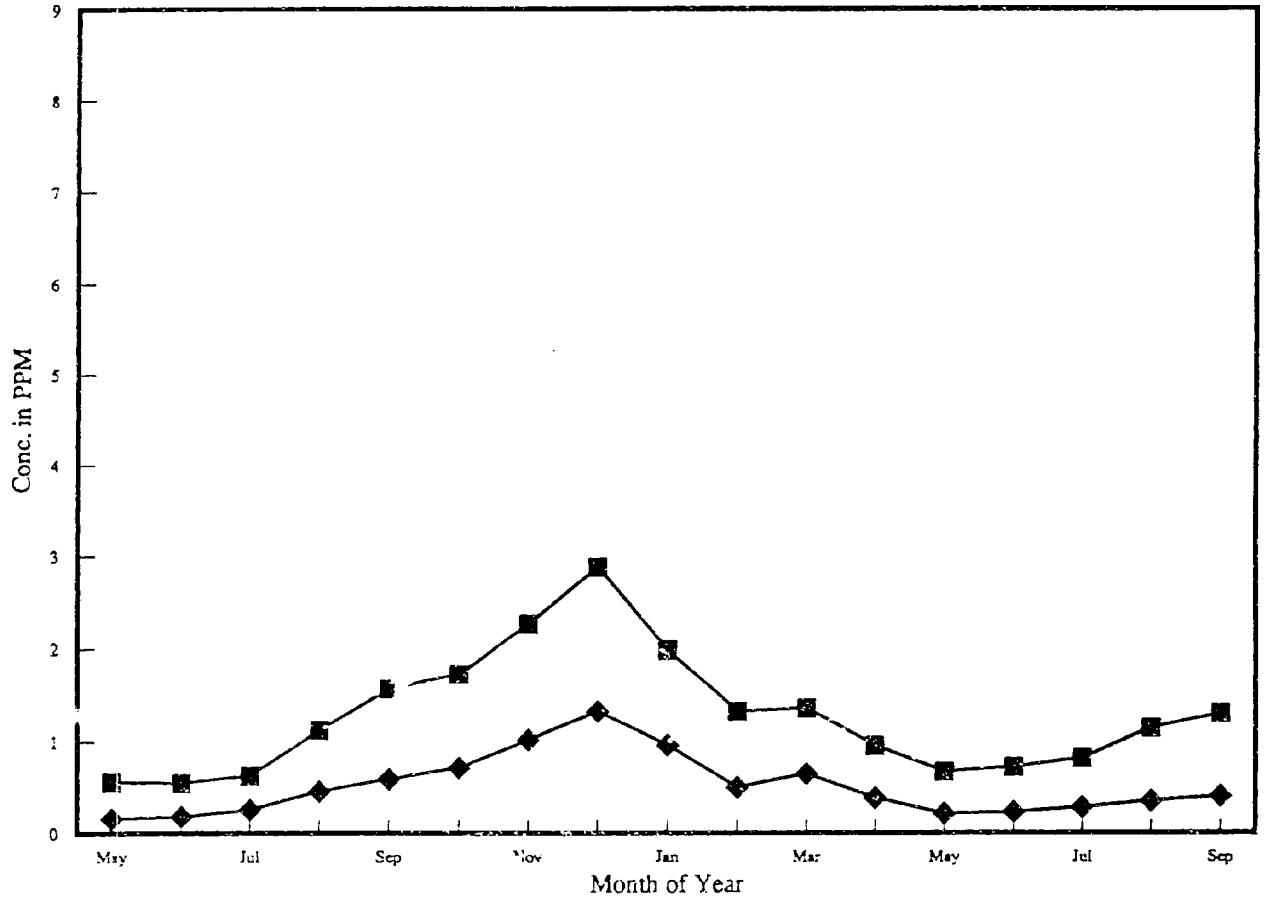

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Figure 5.3-2

Graphical Depiction of Monthly Mean for Carbon Monoxide

(May, 1989-Sept., 1990)

CMP AR FY90

seasons. This increase was primarily due to shallow and intense nighttime surface inversions and concurrent very light winds which developed during these seasons. The high concentrations began to decrease with the approach of spring, warmer temperatures and the more frequent unstable atmospheric conditions.

Monthly summaries of the 1-hour and 8-hour averages are shown in Tables 5.3-1 and 5.3-2, respectively. The maximum observed 1-hour concentration was 8.47 ppm and the maximum 8-hour concentration was 5.95 ppm both in December 1989. The National and Colorado Ambient Air Quality Standards for the 1-hour and 8-hour averages, 35 ppm and 9 ppm, respectively, were never exceeded during the FY90 sample collection period at RMA.

In addition to the seasonal cycle, an apparent diurnal cycle for FY90 is also evident as presented in Figure 5.3-3. As indicated in the FY89 Assessment Report, there are no major stationary sources of carbon monoxide in the RMA area. The high CO levels represent an influx of emissions from vehicles during the Denver metropolitan rush hour between the hours of 0600 MST and 1100 MST. The data collected during FY90 again reflected a similar pattern. There was also a smaller increase in CO concentrations during the hours of 2000 MST and 0200 MST. This occurrence may have been the result of several factors including the onset of the evening inversion, a shift in the wind direction, increased production from nearby power plants and nighttime heating of homes, especially those with woodstoves.

A comparison of the diurnal cycles for the period from May through September of FY89 data to FY90 data is illustrated in Figure 5.3-4. There was a slight increase in the concentrations from FY89 to FY90. It is difficult to account for this, although one explanation may be that prevailing winds shifted from the south in FY89 to the south-southwest in FY90, bringing a slightly greater impact from metropolitan Denver onto the Arsenal. Figures 5.3-5 and 5.3-6 compare the highest 1-hour and 8-hour carbon monoxide concentrations recorded at RMA to two Colorado Department of Health sites, Welby and CAMP, for the period October 1989 through September 1990. These two graphs show that concentrations recorded at RMA were lower than the two Colorado Department of Health locations and significantly lower than the CAMP site for the fall and winter months, when CO concentrations were elevated due to the colder weather.

Individual monthly graphs and tables are presented in Appendix I. These items contain daily maximum, minimum and mean concentrations for each day of each month.

Table 5.3-1 Summary of Carbon Monoxide 1-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.71	1.00	1.36	0.96	0.50	0.64
Maximum	4.83	5.07	8.47	3.88	2.91	4.97
2nd Highest Maximum	3.86	3.95	7.74	3.75	2.67	4.32
Minimum	0.23	0.49	0.73	0.10	0.10	0.10

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.39	0.21	0.23	0.28	0.35	0.40
Maximum	2.57	1.77	1.49	2.10	2.90	2.52
2nd Highest Maximum	2.01	1.65	1.48	1.80	1.77	2.39
Minimum	0.10	0.10	0.10	0.10	0.10	0.10

Mean for Entire Period 0.60

[1] Federal and Colorado Ambient Air Quality Standard for maximum 1-hour average values is 35 ppm, not to be exceeded more than once a year.

Table 5.3-2 Summary of Carbon Monoxide 8-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.71	1.00	1.36	0.96	0.50	0.64
Maximum	2.29	2.98	5.95	2.78	1.88	3.66
2nd Highest Maximum	2.27	2.90	5.94	2.78	1.83	3.53
Minimum	0.25	0.54	0.76	0.10	0.10	0.10

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.39	0.21	0.23	0.28	0.35	0.40
Maximum	1.21	1.09	0.88	1.37	1.05	1.52
2nd Highest Maximum	1.20	1.08	0.86	1.35	1.04	1.50
Minimum	0.10	0.10	0.10	0.10	0.10	0.10

Mean for Entire Period 0.60

[1] Federal and Colorado Ambient Air Quality Standard for maximum 8-hour average values is 9 ppm, not to be exceeded more than once a year.

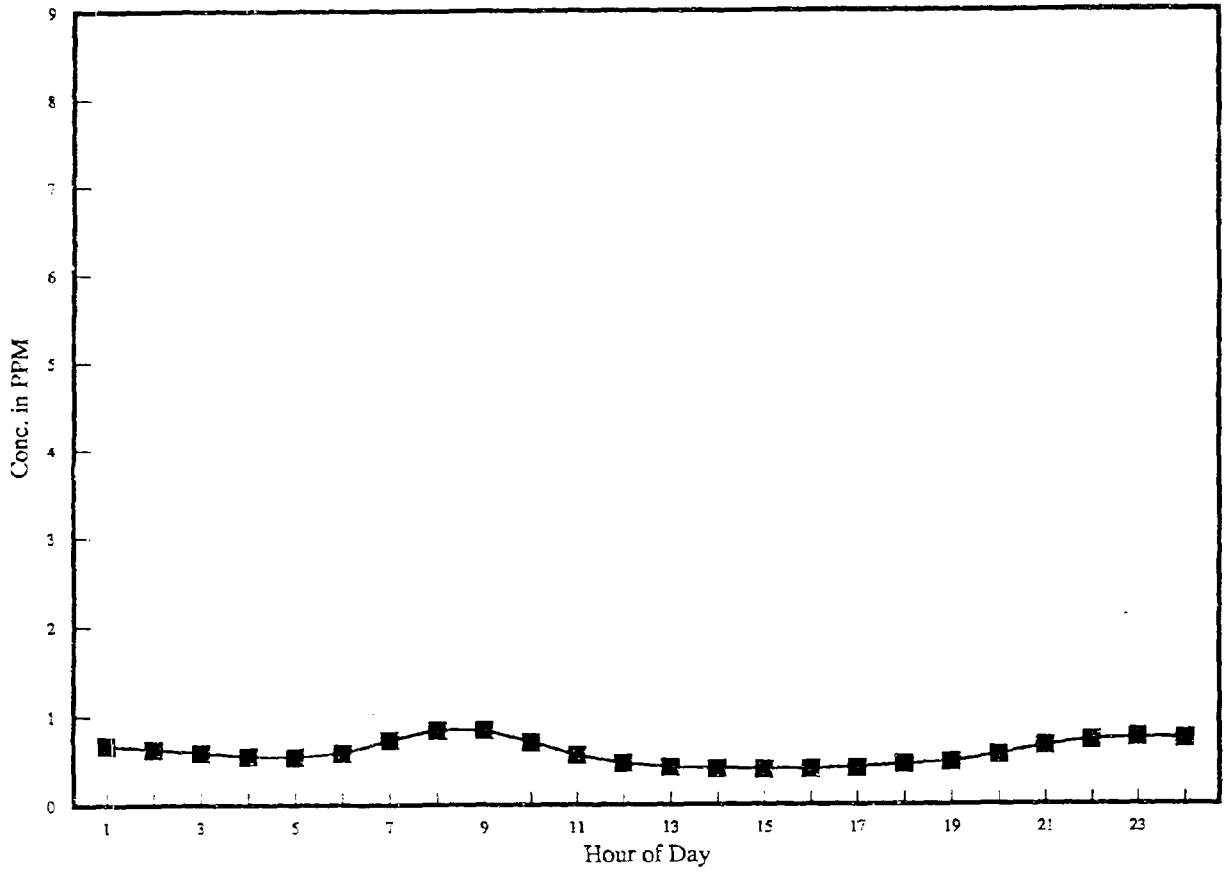

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Figure 5.3-3

Graphical Depiction of Diurnal Cycle for Carbon Monoxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

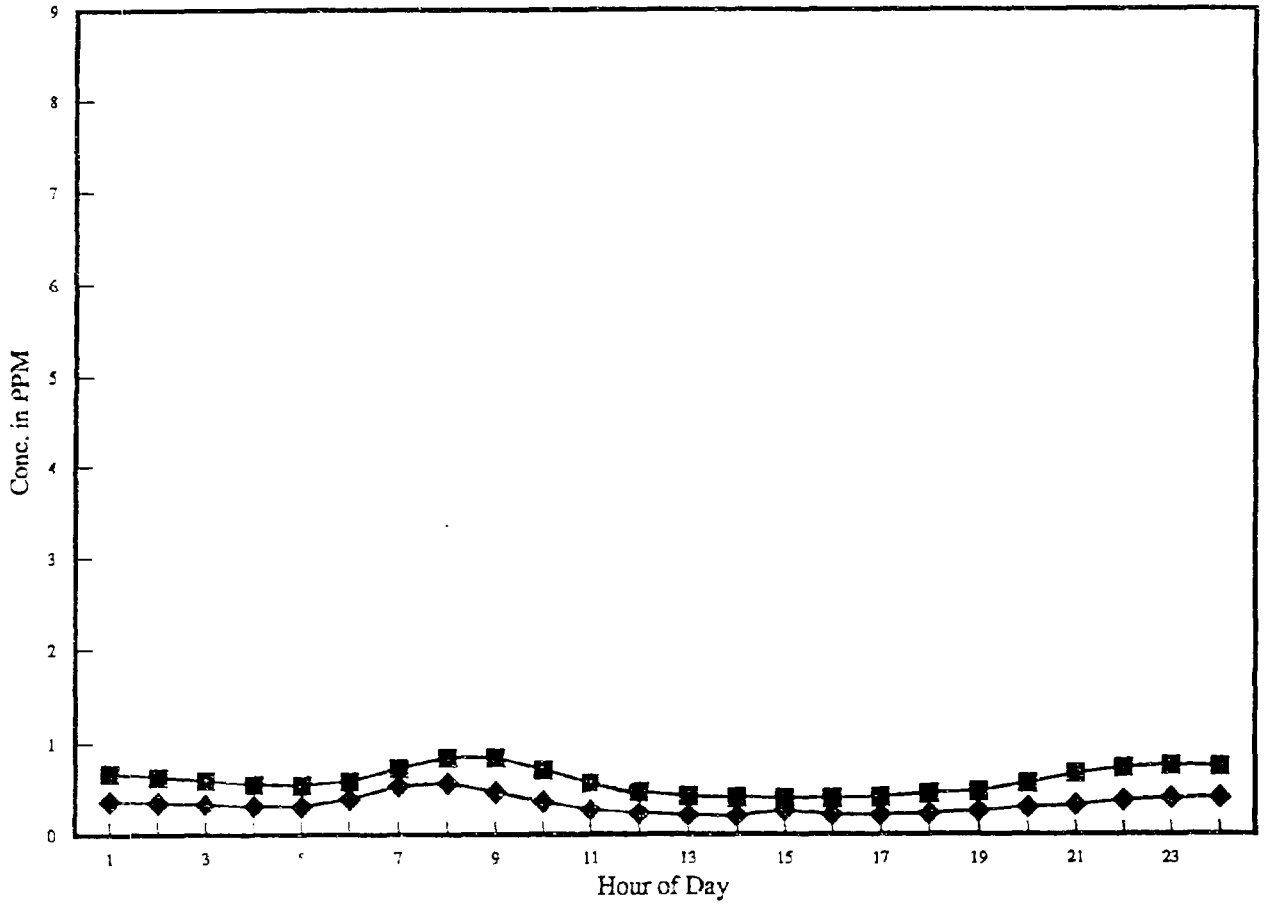

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Figure 5.3-4

Graphical Depiction of Diurnal Comparison for Carbon Monoxide (May-September)

CMP AR FY90

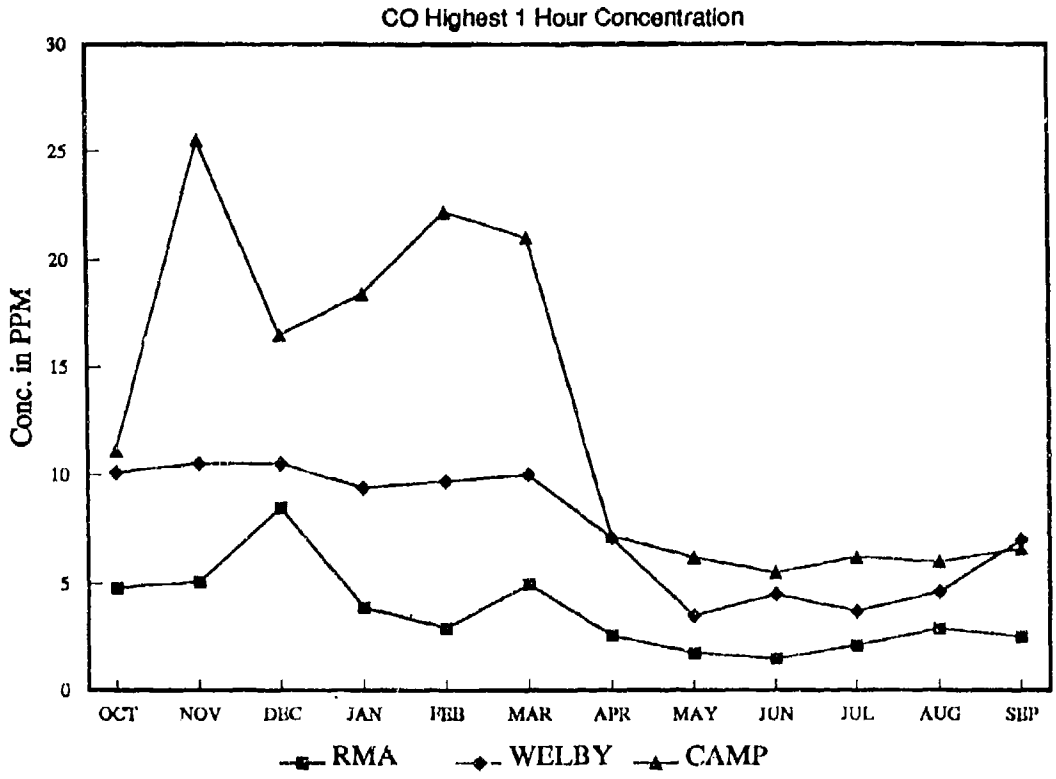

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Figure 5.3-5

CMP and Colorado Department of Health Sites 1-Hour Carbon Monoxide Values (Oct., 1989-Sept., 1990)

CMP AR FY90

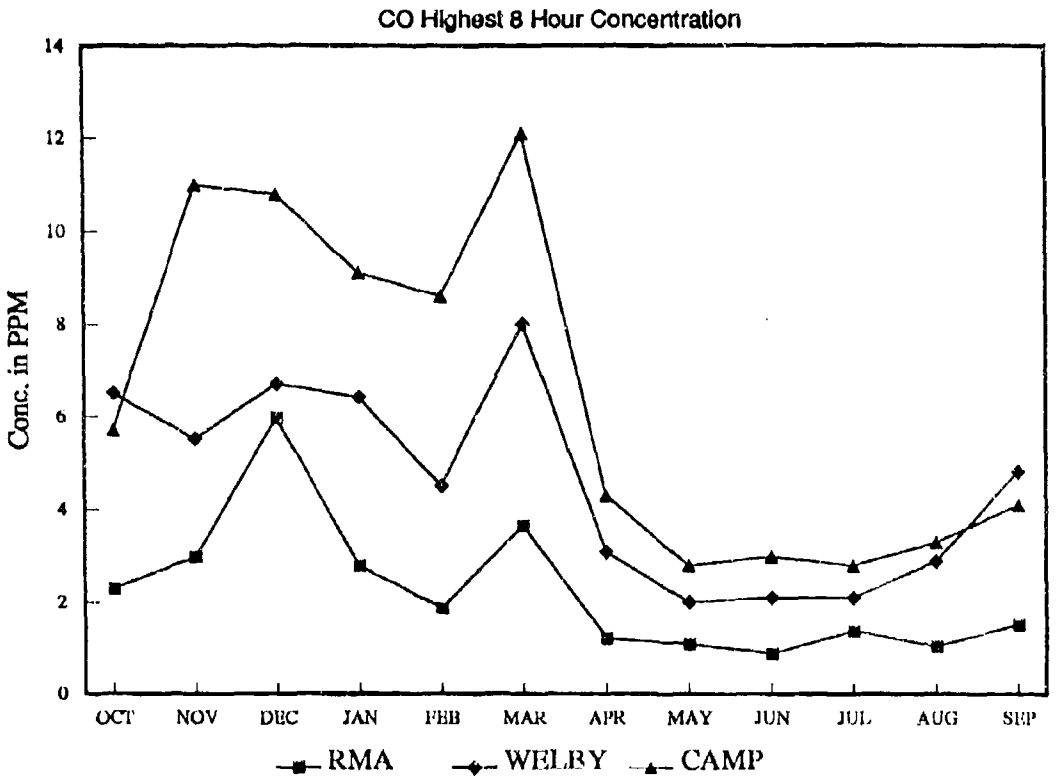

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Figure 5.3-6
CMP and Colorado Department of Health Sites 8-Hour Carbon Monoxide Values (Oct., 1989-Sept., 1990)

CMP AR FY90

5.4 OZONE

The continuous series of daily mean and 1-hour maximum ozone concentrations at the RMA site for FY90 are given in Figures 5.4-1a and 5.4-1b, respectively. These graphs also illustrate a very evident annual cycle for ozone. During the late spring and through the summer, generation of ozone increased and peak concentrations were obtained during July and August. Also seen in these graphs are the evident minimum concentrations for ozone obtained during the winter months. The cycle is also represented in Figure 5.4-2 which displays the mean monthly maximum and the monthly mean ozone values for the entire CMP FY89 and FY90 period from May 1989 to September 1990 (highlighting the winter measurements). Figure 5.4-3 displays the daily mean concentrations for ozone from May 1989 through September 1990. It is apparent from these depictions that, as might be expected, the summer months were peak months while the winter months represented periods of minimum ozone production.

Monthly summaries of the 1-hour averages are given in Table 5.4-1. A very distinct diurnal pattern for ozone is illustrated in Figure 5.4-4. Peak ozone concentrations occurred between the hours of 1300 MST and 1500 MST, when solar radiation intensity was at a maximum and played a major role in the formation of ozone. Ozone generation decreased after the peak hours and stabilized to minimum levels between 2400 MST through 0500 MST. During the hours of 0500 MST and 0700 MST, ozone concentrations were further reduced.

The highest ozone concentration, 0.118 ppm, was recorded on June 30, 1990, at 1500 MST. This concentration is slightly lower than the primary 1-hour National and Colorado Ambient Air Quality Standard of 0.120 ppm for ozone. This peak concentration for the year was recorded during an intense heat wave in the Denver metropolitan area that lasted for 6 consecutive days during the end of June and the first part of July. Maximum temperatures (in degrees Fahrenheit) recorded during this period were 96.6, 94.1, 98.6, 97.5, 98.0 and 97.5, for June 27, 1990 to July 2, 1990.

A comparison of the diurnal pattern for the period from May through September of both FY89 and FY90 is shown in Figure 5.4-5. Lower mean concentrations were observed in FY90 compared to those of FY89. This may be attributed to any number of causes, such as the number of cloudy days in FY90. Figure 5.4-6 depicts the overall mean and maximum hourly concentrations for the period from May 6, 1989, through September 30, 1990. The highest ozone values were recorded during the summer months between the hours of 1300 MST to 1500 MST as shown in the figure.

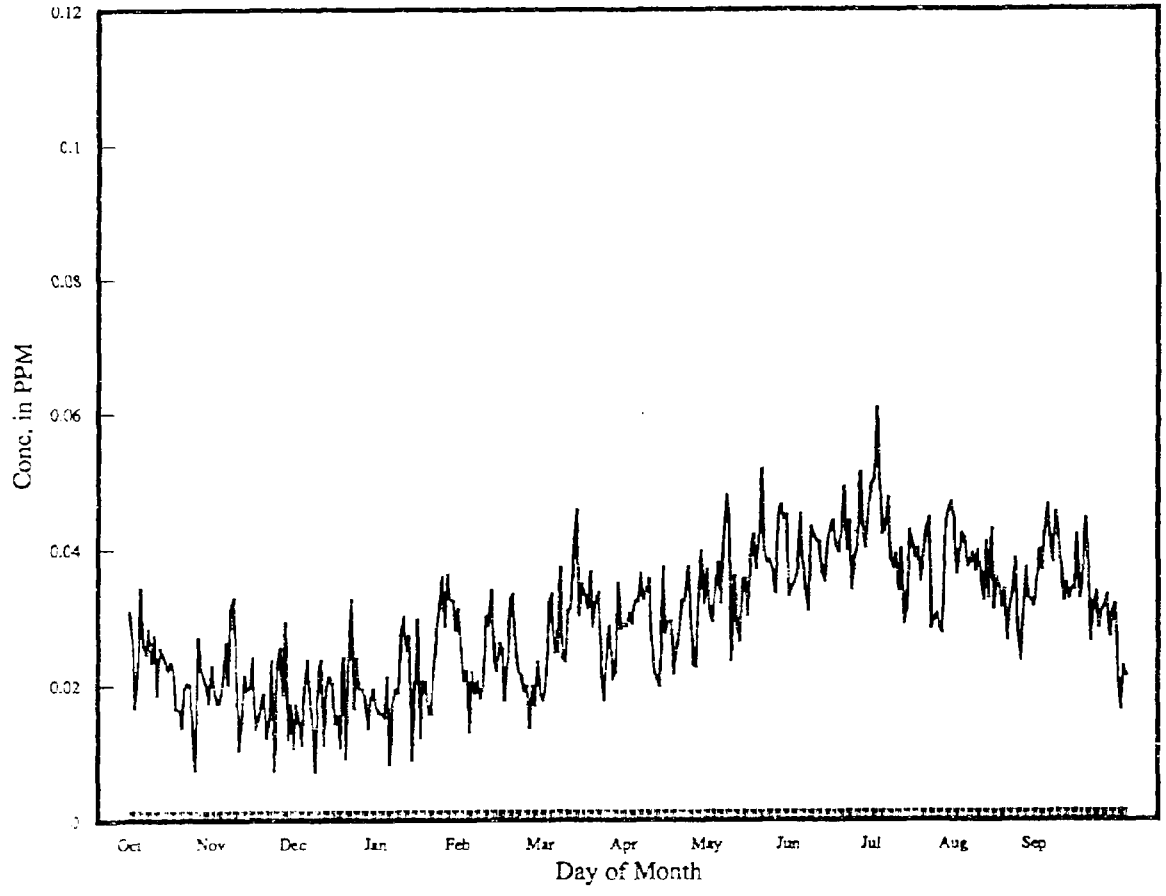

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Figure 5.4-1a
Graphical Depiction of Daily Mean
for Ozone FY90
(Oct. 1, 1989-Sept. 30, 1990)
CMP AR FY90

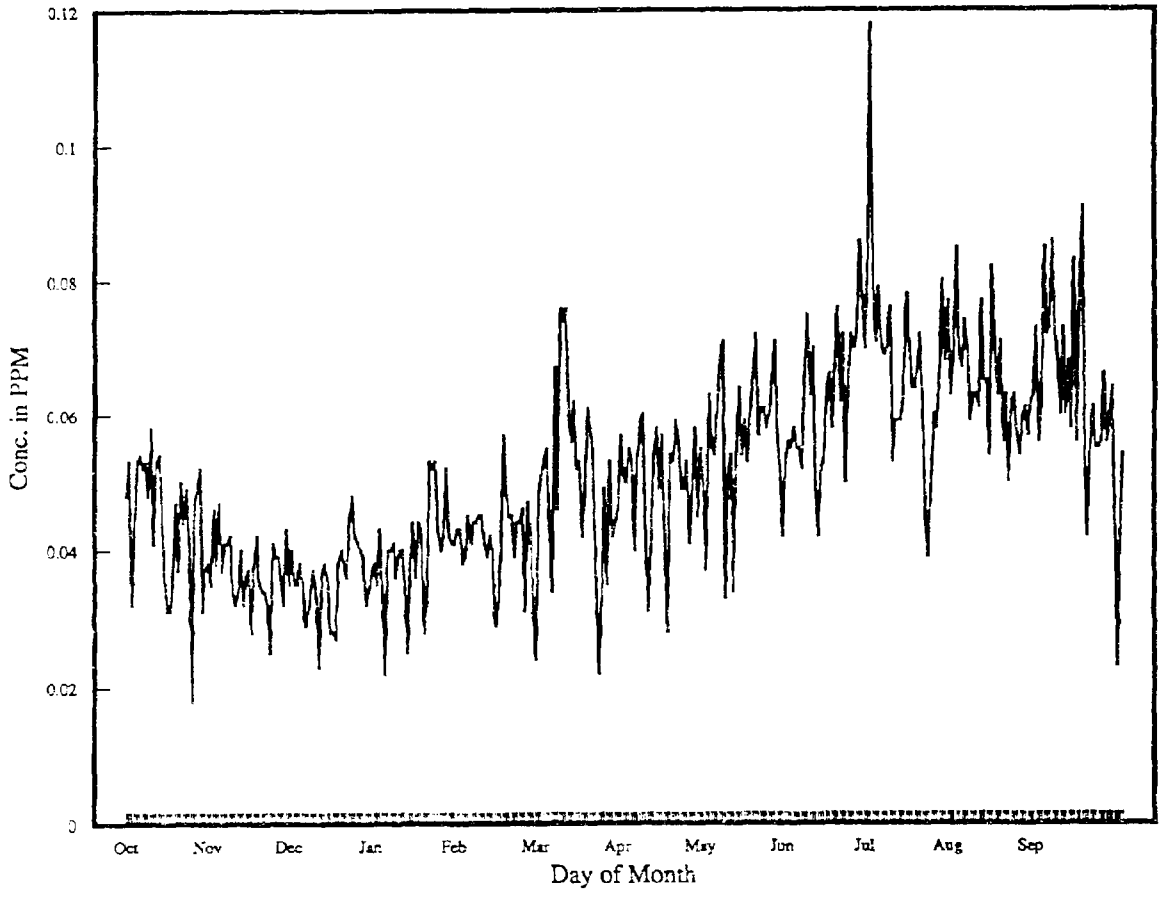

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Figure 5.4-1b

Graphical Depiction of Daily Maximum for Ozone FY90
(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

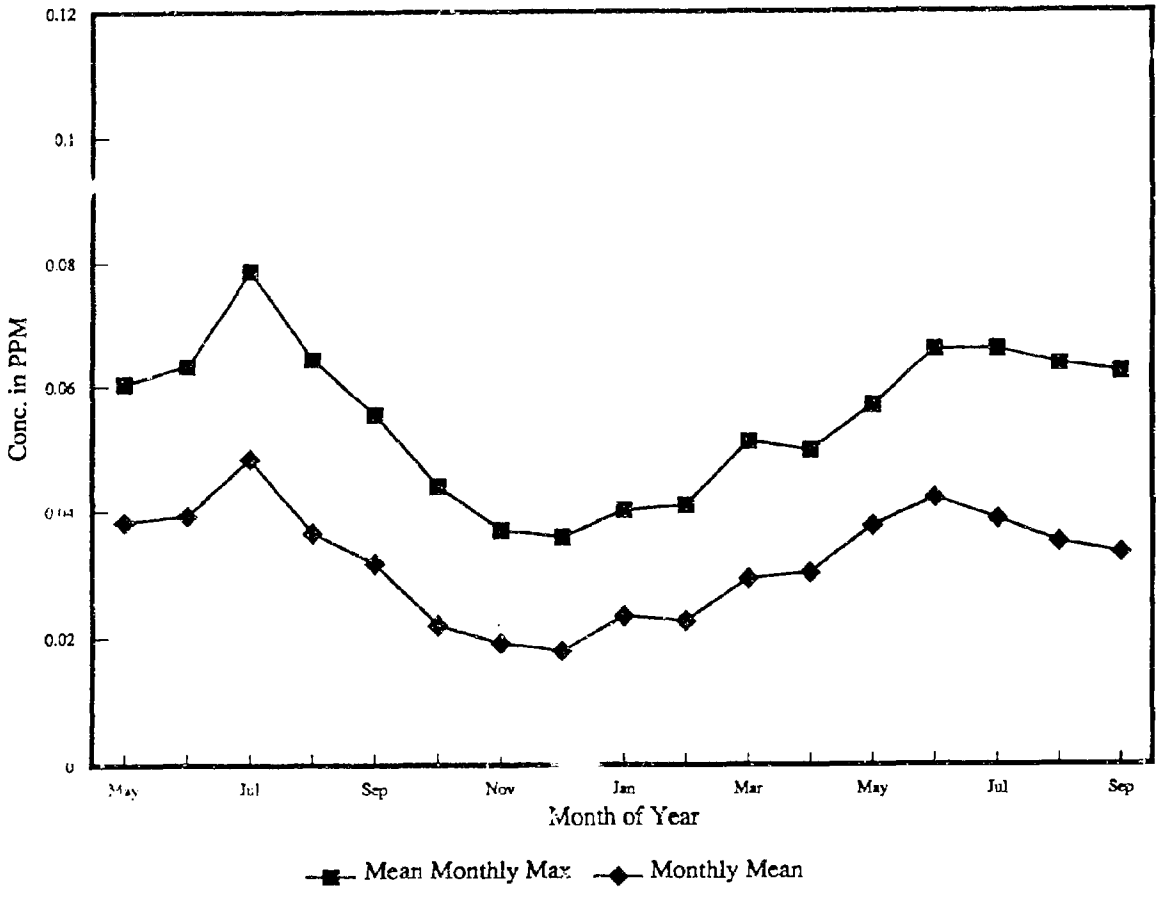

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Figure 5.4-2
Graphical Depiction of Monthly Mean for Ozone
(May, 1989-Sept., 1990)

CMP AR FY90

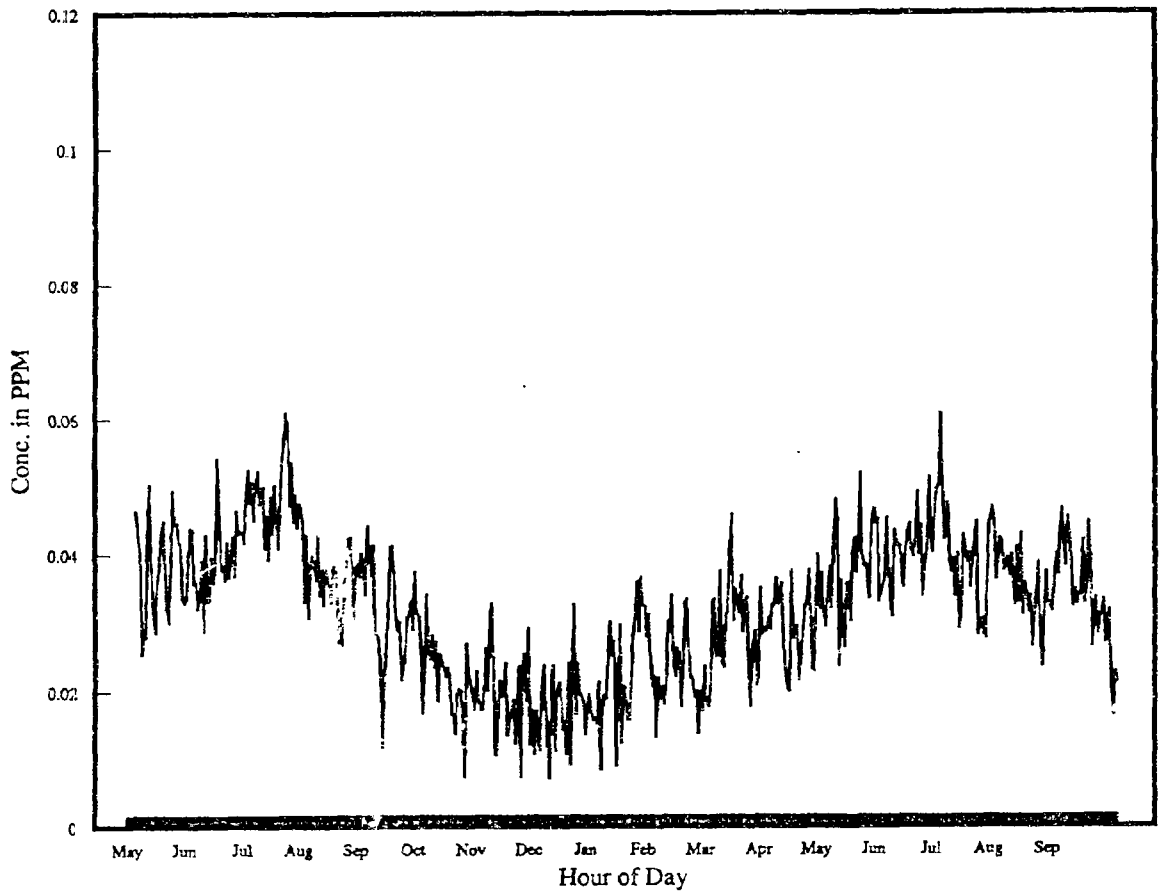

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Figure 5.4-3
Graphical Depiction of Daily Mean for Ozone
(May 6, 1989-Sept. 30, 1990)

CMP AR FY90

Table 5.4-1 Summary of Ozone 1-Hour Average Values in ppm[1] October, 1, 1989 (0'00 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.022	0.019	0.018	0.023	0.023	0.030
Maximum	0.058	0.046	0.048	0.053	0.057	0.076
2nd Highest Maximum	0.058	0.046	0.046	0.053	0.057	0.076
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.030	0.038	0.042	0.039	0.035	0.033
Maximum	0.060	0.072	0.118	0.085	0.082	0.091
2nd Highest Maximum	0.059	0.072	0.103	0.084	0.079	0.090
Minimum	0.001	0.001	0.001	0.001	0.001	0.001
Mean for Entire Period	0.029					

[1] Federal and Colorado Ambient Air Quality Standard for maximum 1-hour average values is 0.120 ppm. The statistically estimated number of days with exceedances averaged over a 3-year period is not to be more than 1 per year.

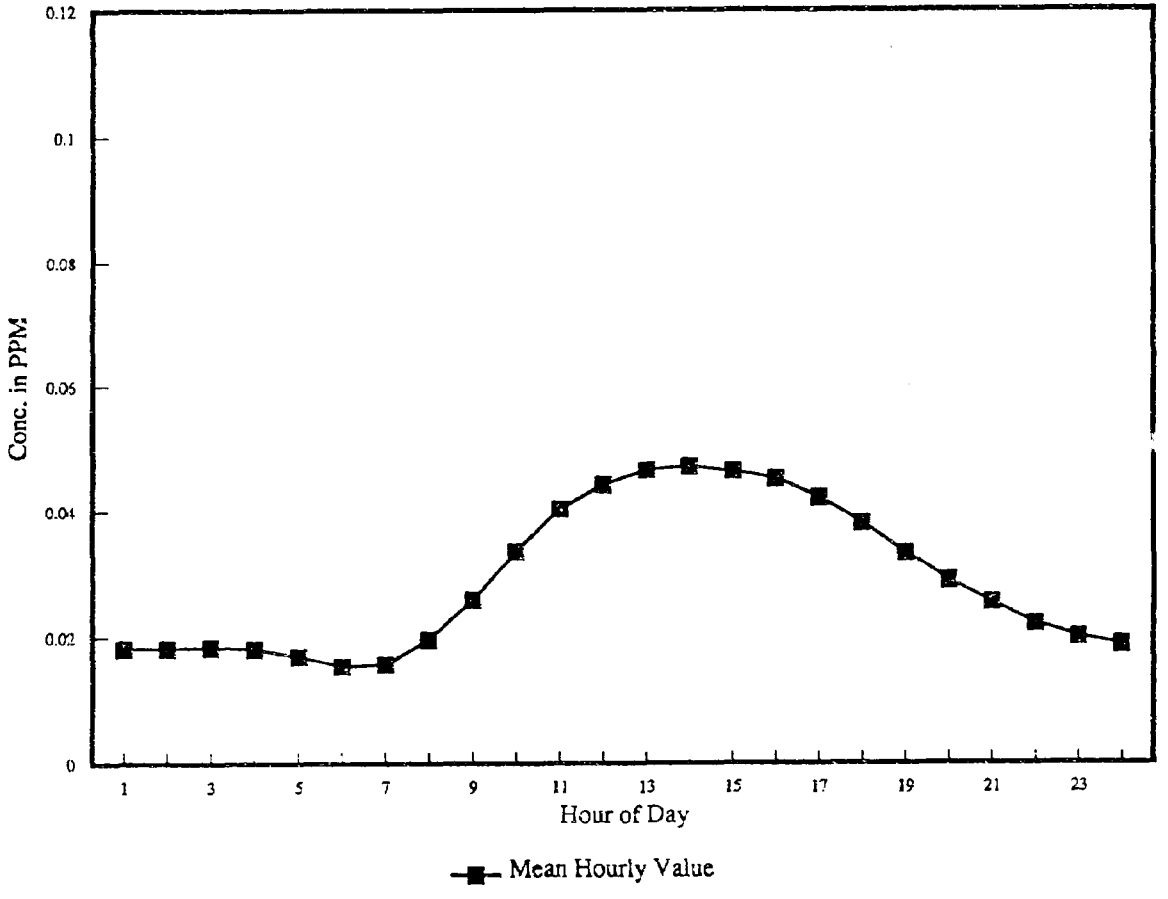

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Figure 5.4-4

Graphical Depiction of Diurnal Cycle for Ozone FY90

(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

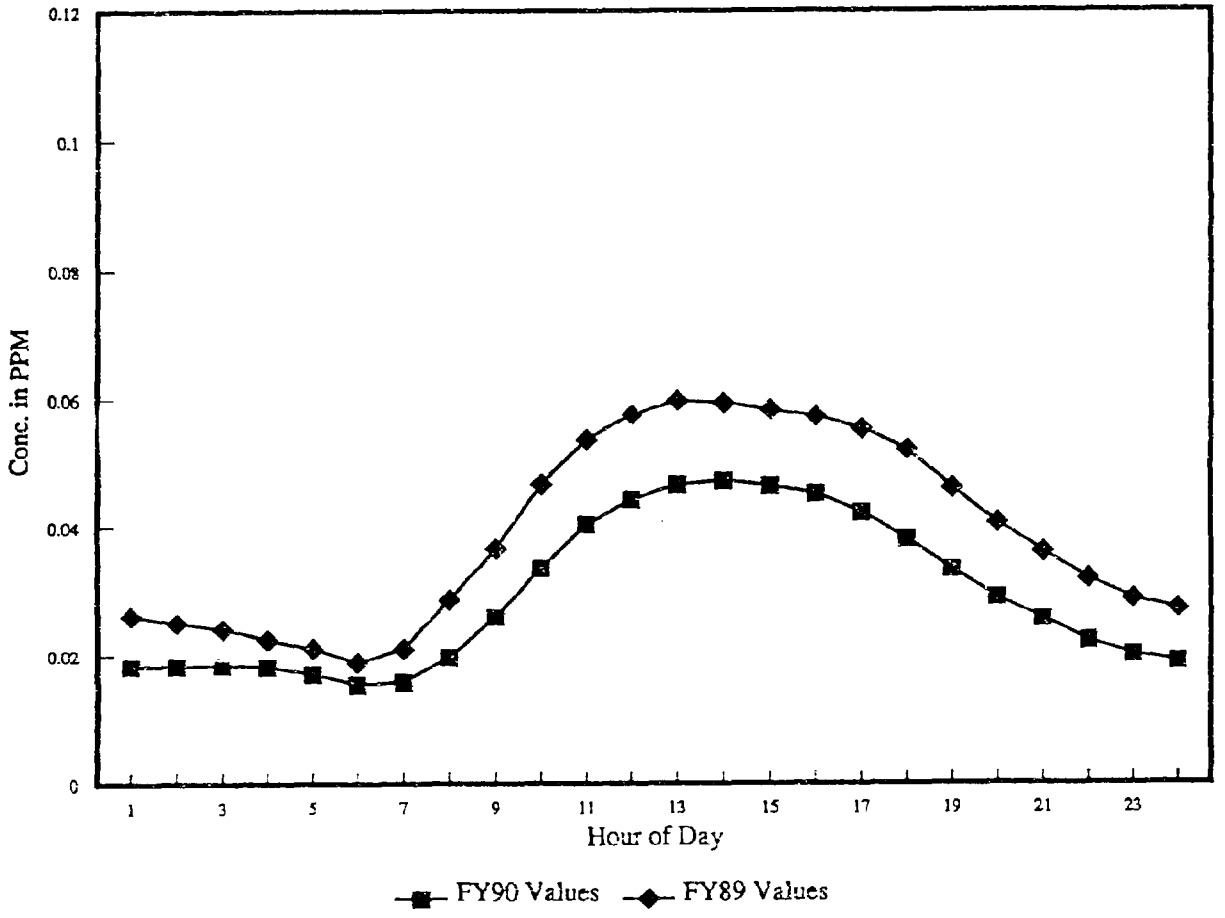

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Figure 5.4-5

Graphical Depiction of Diurnal Comparison for Ozone (May-September)

CMP AR FY90

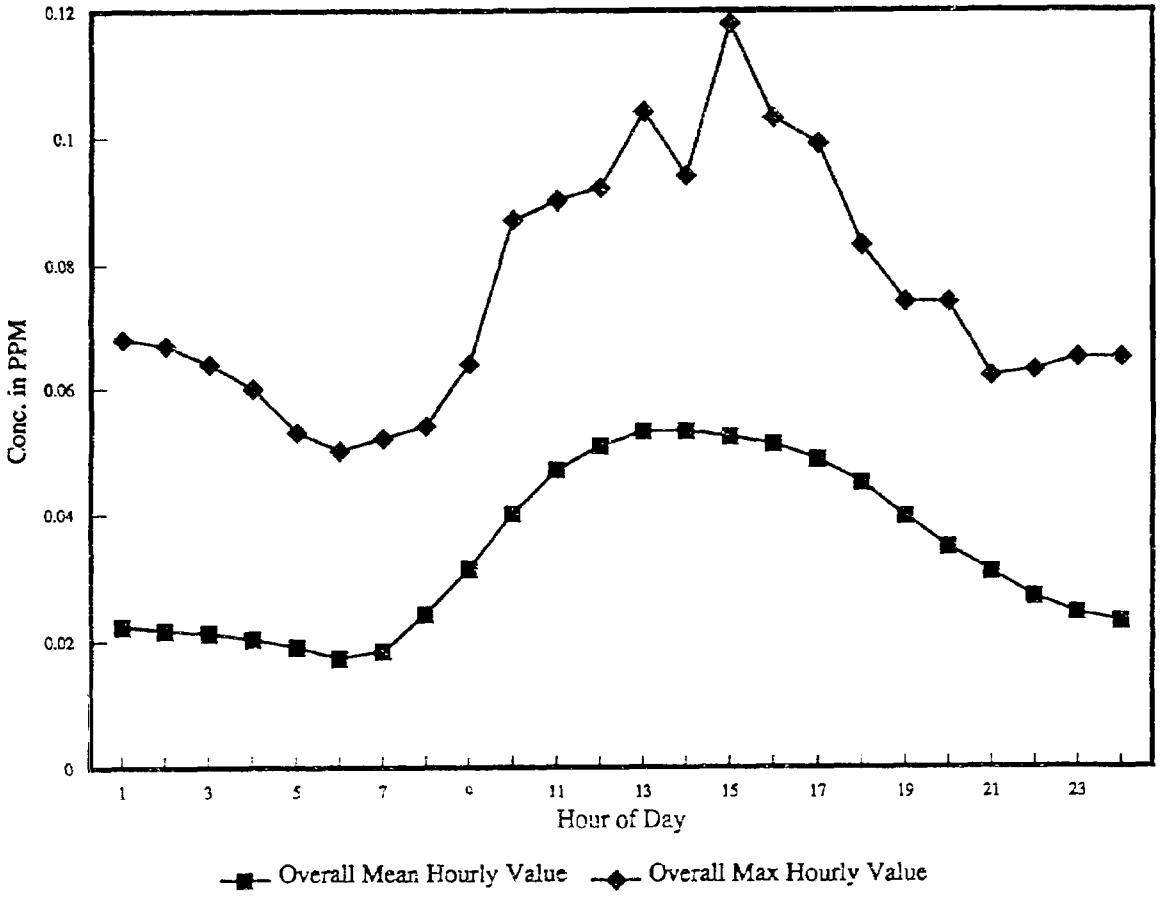

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Figure 5.4-6

Graphical Depiction of Overall Mean for Ozone at CDH Site, (May 6, 1989-Sept. 30, 1990)

Figure 5.4-7 compares the highest 1-hour ozone concentrations recorded at RMA to the two Colorado Department of Health sites for the period October 1989 through September 1990. Concentrations at RMA were slightly higher than the two Colorado Department of Health locations, most notably during the fall and winter seasons.

Individual monthly graphs and tables are presented in Appendix I. These items contain daily maximum, minimum and mean concentrations for each day of each month.

5.5 SULFUR DIOXIDE

The series of daily mean and 1-hour maximum sulfur dioxide concentrations at the RMA site for FY90 are shown in Figures 5.5-1a and 5.5-1b, respectively. During this data collection period, there were numerous occasions where the daily maximum concentration was several times greater than the daily mean concentration, most likely reflecting the transport of concentrations onto the Arsenal from metropolitan Denver SO_2 sources (see Section 5.7). There were also instances in which the daily maximum concentration was nearly the same as the daily mean concentration, reflecting periods when migration of pollutants from metropolitan Denver was not toward the Arsenal. There appears to have been no strong annual cycle for sulfur dioxide as shown in Figure 5.5-2, which provides mean monthly maximum and monthly mean values. There was, however, a very slight rise in sulfur dioxide monthly mean concentrations for the winter months of November, December and January. This may be attributed to the increase in surface inversions, persistent wind direction or the increase in emissions from major nearby SO_2 sources

A cumulative picture is represented in Figure 5.5-3, which shows the daily mean concentrations for FY89 and FY90 from May 6, 1989, through September 30, 1990. Monthly summaries of the 1-hour, 3-hour and 24-hour averages are given in Tables 5.5-1, 5.5-2 and 5.5-3, respectively. During the data collection period for FY90, there were no violations of Colorado Ambient Air Quality Standards for SO_2.

The diurnal pattern for sulfur dioxide at RMA is illustrated in Figure 5.5-4. A slight increase in SO_2 concentrations is evident during the hours of 0700 MST through 1100 MST. As indicated in the FY89 Assessment Report, there are no major stationary sources of SO_2 located within the RMA boundary. This increase in sulfur dioxide may have resulted from the morning rush hour of the Denver metropolitan area, although SO_2 emissions from vehicle traffic are small. Another explanation may be increased power generations and other industrial activity coupled with early morning inversions.

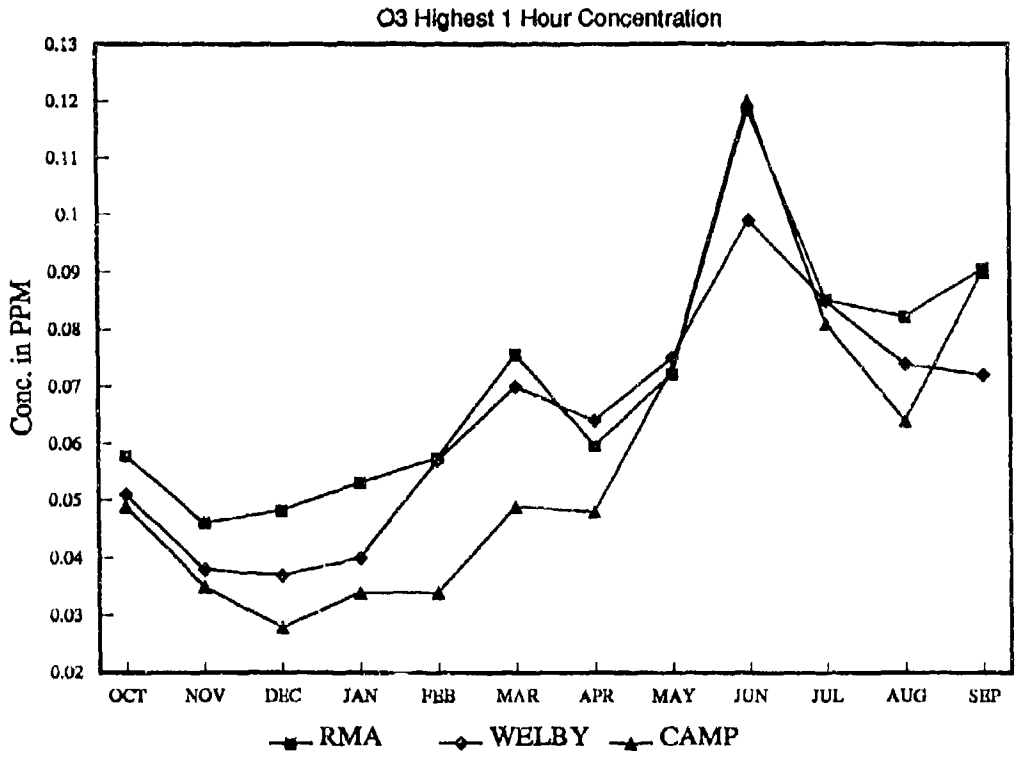

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Figure 5.4-7

CMP and Colorado Department of Health Sites 1-Hour Ozone Values (Oct., 1989-Sept., 1990)

CMP AR FY90

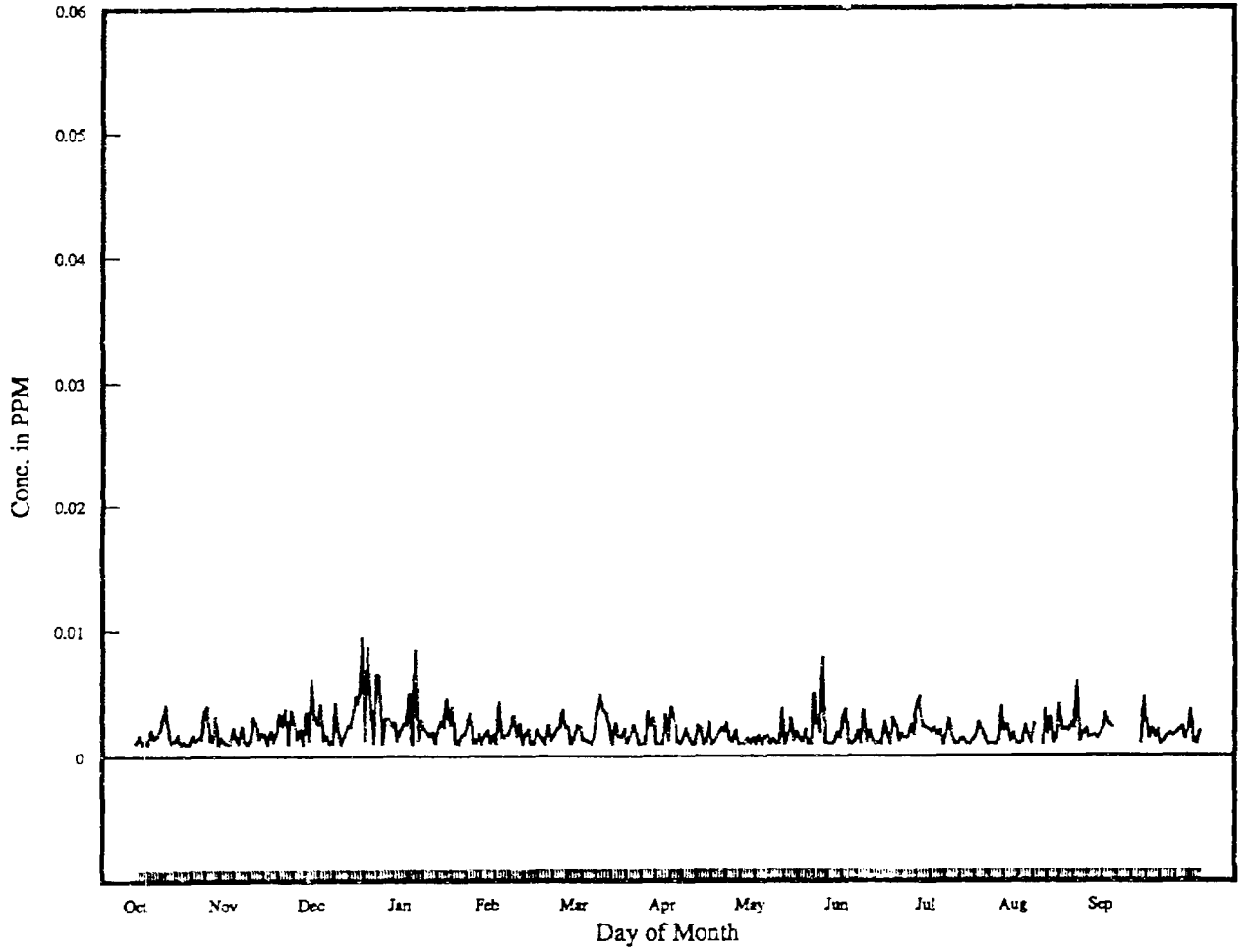

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Figure 5.5-1a

Graphical Depiction of Daily Mean for Sulfur Dioxide FY90 (Oct. 1, 1990-Sept. 30, 1990)

CMP AR FY90

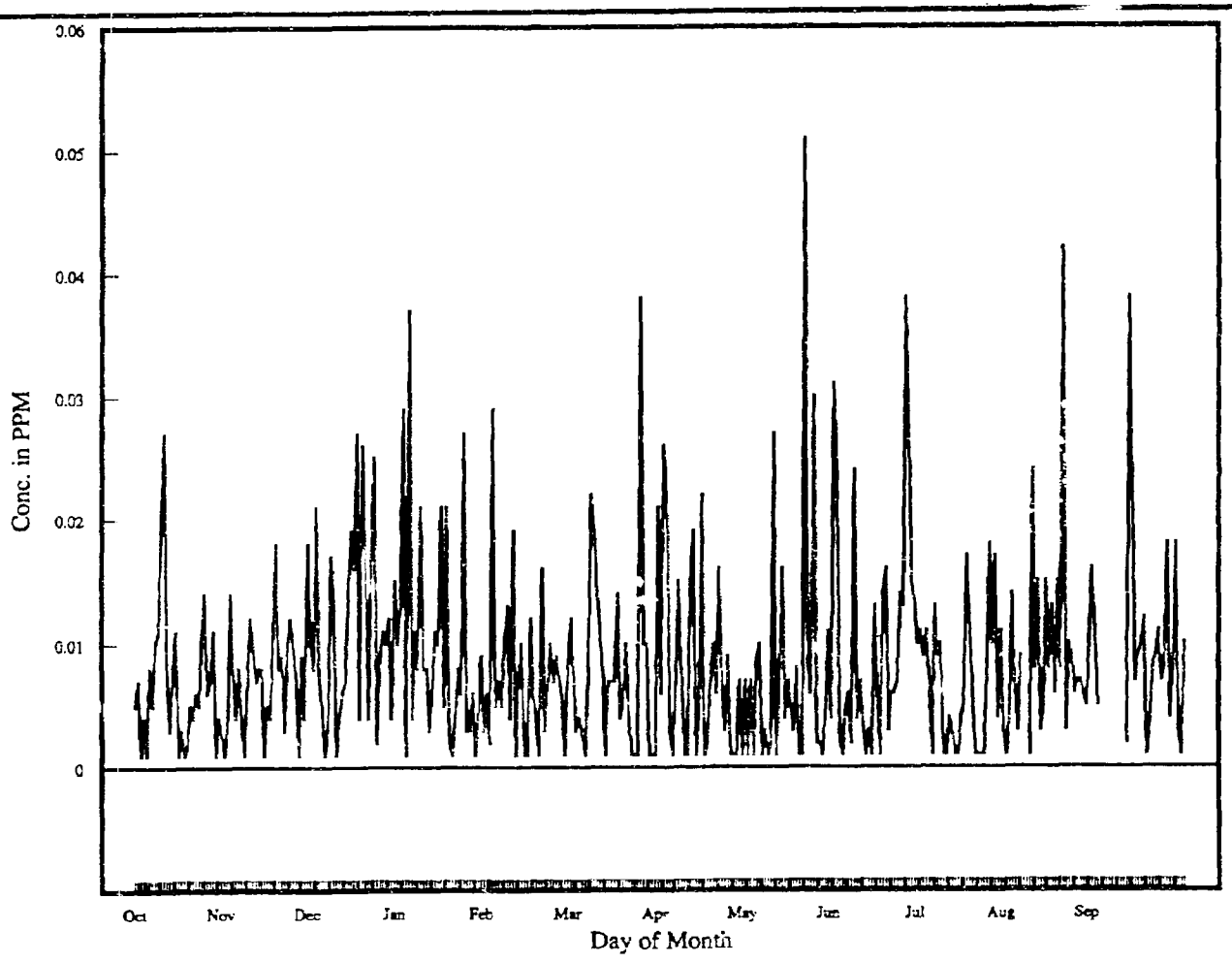

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Figure 5.5-1b

Graphical Depiction of Daily Maximum for Sulfur Dioxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

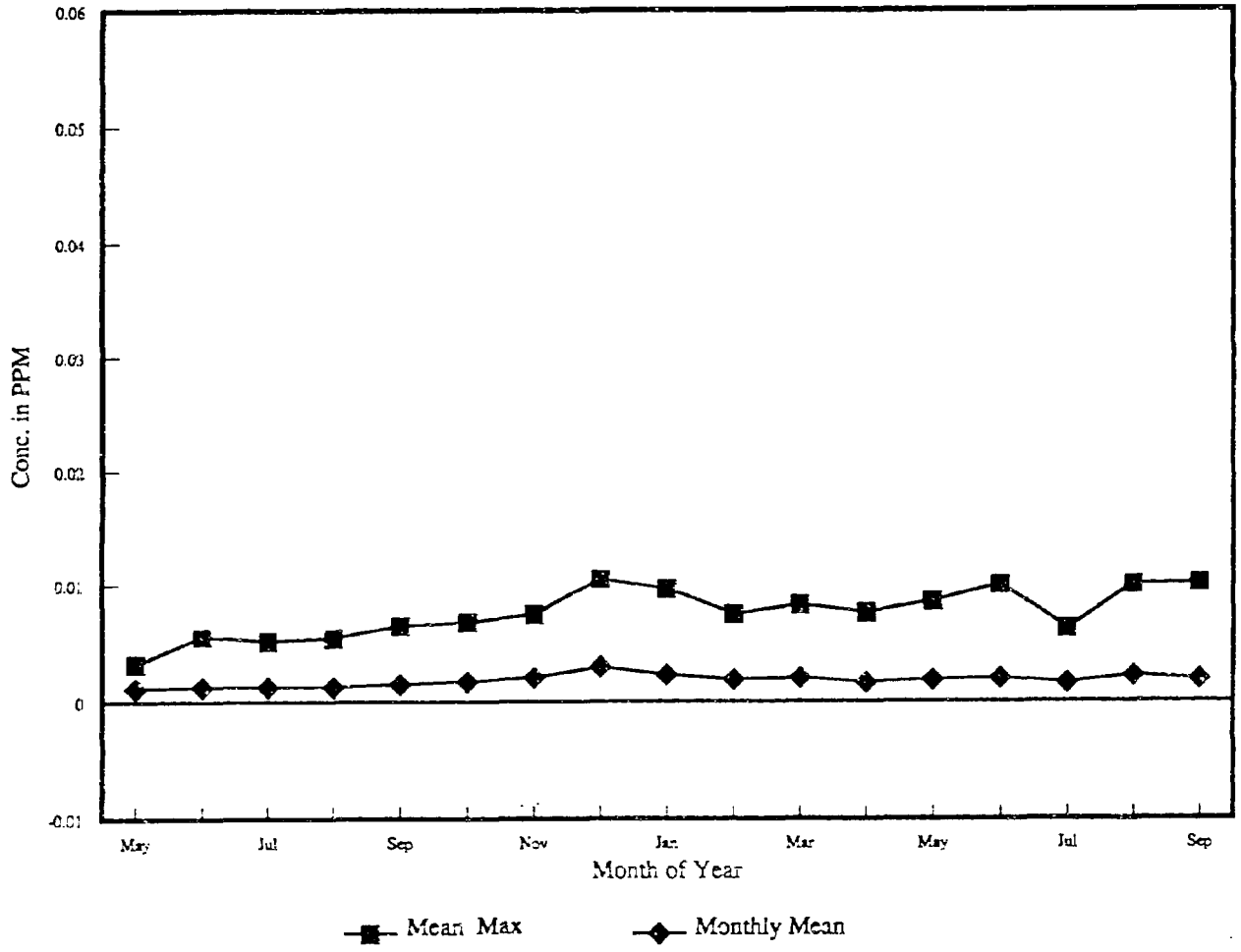

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Figure 5.5-2

Graphical Depiction of Monthly Mean for Sulfur Dioxide
(May, 1989-September, 1990)

CMP AR FY90

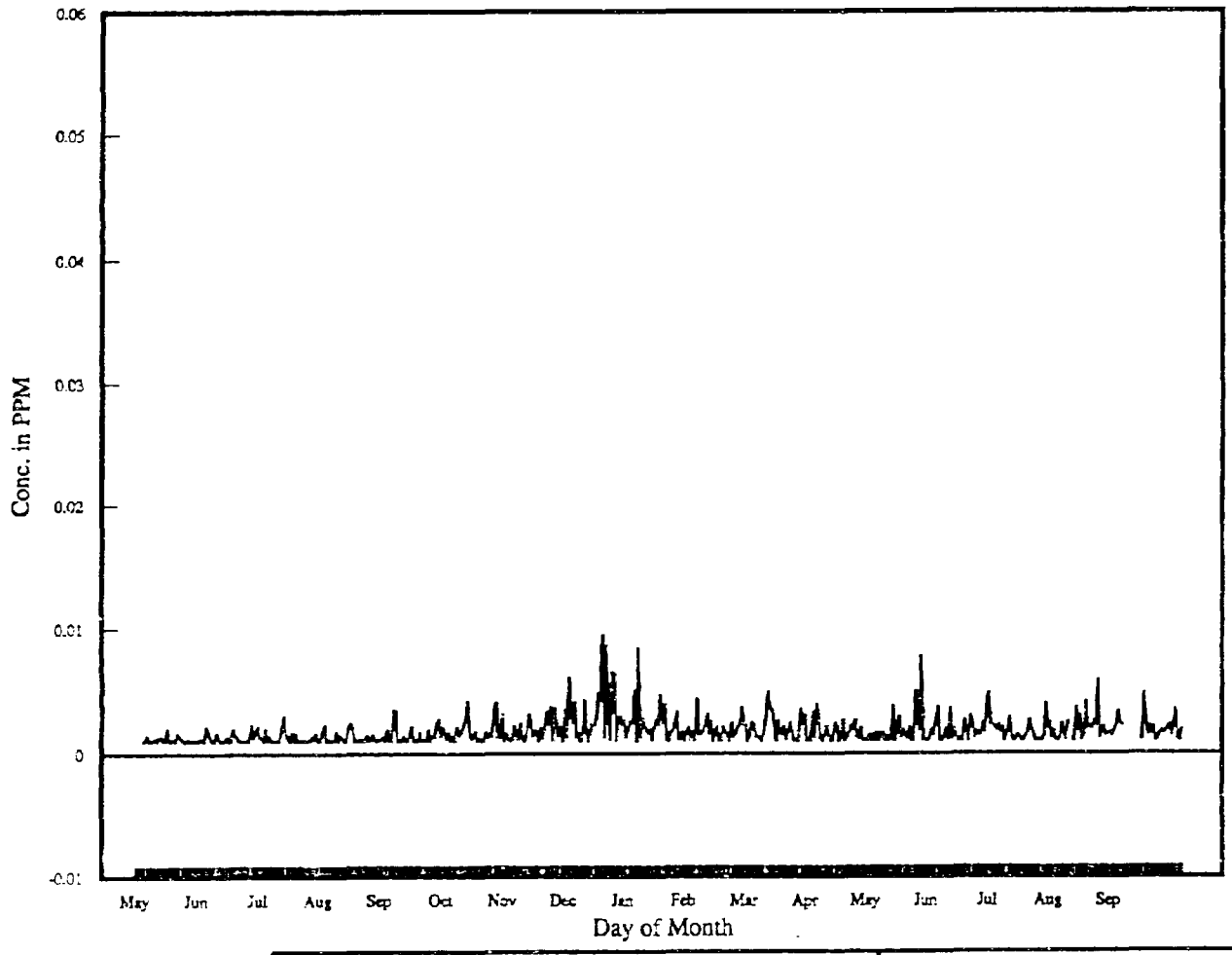

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Figure 5.5-3
Graphical Depiction of Daily Mean for Sulfur Dioxide
(May 6, 1989-Sept. 30, 1990)

CMP AR FY90

Table 5.5-1 Summary of Sulfur Dioxide 1-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.002	0 002	0.003	0.002	0.002	0.002
Maximum	0.027	0.018	0.027	0.037	0.029	0.038
2nd Highest Maximum	0.020	0.018	0.026	0.032	0.021	0.022
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.001	0.001	0.001	0.001	0.002	0.002
Maximum	0.026	0.051	0.038	0.018	0.042	0.038
2nd Highest Maximum	0.022	0.031	0.028	0.017	0.024	0.031
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

Mean for Entire Period 0.002

[1] National and Colorado Ambient Air Quality Standard for annual arithmetic mean is 0.030 ppm. (There is no NAAQ 1-hour standard for SO_2.)

Table 5.5-2 Summary of Sulfur Dioxide 3-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.002	0.002	0.003	0.002	0.002	0.002
Maximum	0.016	0.018	0.024	0.030	0.022	0.020
2nd Highest Maximum	0.015	0.017	0.022	0.027	0.018	0.018
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.002	0.002	0.002	0.002	0.002	0.002
Maximum	0.020	0.029	0.020	0.012	0.029	0.028
2nd Highest Maximum	0.017	0.028	0.020	0.012	0.022	0.036
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

Mean for Entire Period 0.002

[1] Federal and Colorado Ambient Air Quality Standard for maximum 3-hour average values is 0.500 ppm, not to be exceeded more than once per year.

Table 5.5-3 Summary of Sulfur Dioxide 24-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.002	0.002	0.003	0.002	0.002	0.002
Maximum	0.006	0.006	0.010	0.021	0.005	0.006
2nd Highest Maximum	0.006	0.006	0.010	0.012	0.005	0.006
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.002	0.002	0.002	0.002	0.002	0.002
Maximum	0.005	0.008	0.006	0.004	0.009	0.006
2nd Highest Maximum	0.004	0.008	0.006	0.004	0.009	0.005
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

Mean for Entire Period 0.002

[1] Federal and Colorado Ambient Air Quality Standard for maximum 24-hour average values is 0.140 ppm, not to be exceeded more than once per year.

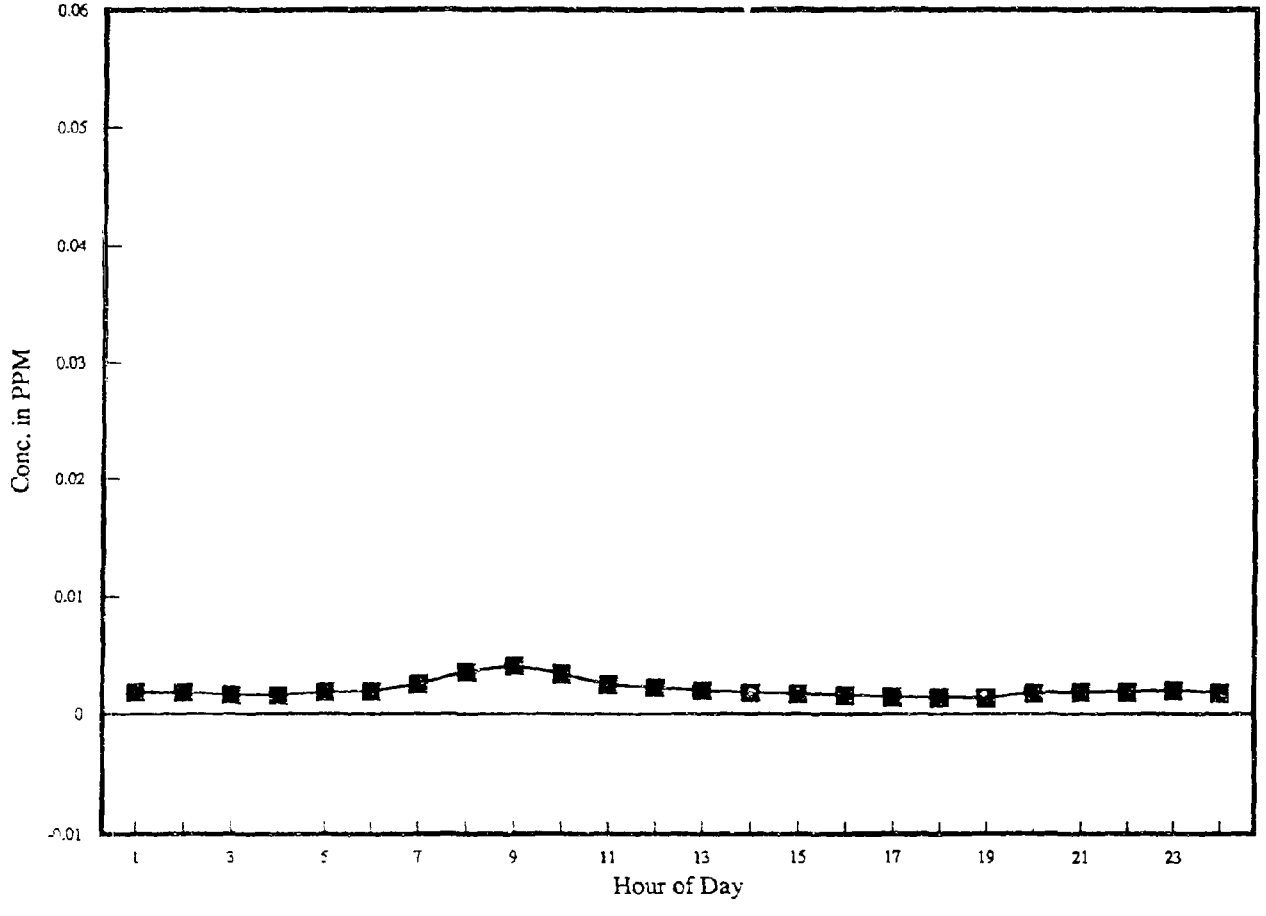

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Figure 5.5-4

Graphical Depiction of Diurnal Cycle for Sulfur Dioxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

A comparison of the diurnal patterns for the period from May through September for FY89 and FY90 is shown in Figure 5.5-5. This graph shows a slight increase in the overall FY90 diurnal pattern when compared to FY89, although this pattern may be attributable to the fact that FY89 data included only the May-September values.

An overall diurnal pattern for the extended period May 6, 1989, through September 30, 1990, and the overall maximum concentrations for each hour during the same period is depicted in Figure 5.5-6. Peak concentrations occurred at varying periods during the day, reflecting inversion conditions, wind flow patterns and source emissions for individual events. One such event, a maximum SO_2 concentration of 0.051 ppm measured at 0800 MST on May 21, 1990, is discussed in the case study examples provided in Section 5.7.

Figures 5.5-7 and 5.5-8 compare the highest 3-hour and 24-hour sulfur dioxide concentrations recorded at RMA to two Colorado Department of Health sites for the period October 1989 through September 1990. The RMA site recorded lower values than the two Colorado Department of Health sites, and considerably smaller values than at the CAMP location.

Individual monthly graphs and tables are presented in Appendix I. These items contain daily maximum, minimum and mean concentrations for each day of each month.

5.6 Nitric Oxide, Nitrogen Dioxide and Nitrogen Oxides

Nitric oxide (NO), nitrogen dioxide (NO_2) and nitrogen oxides (NO_x) data exhibited similar patterns through the data collection period for FY90. This is supported by the following: 1) NO and NO_2 have similar sources and removal mechanisms, and 2) the concentration of NO_x is the sum of NO and NO_2 concentrations.

The series of daily mean concentrations for NO, NO_2 and NO_x are shown in Figures 5.6-1a, 5.6-1b and 5.6-1c, respectively. The series of daily maximum concentrations for NO, NO_2 and NO_x are shown in Figures 5.6-2a, 5.6-2b and 5.6-2c, respectively. These graphs show an annual cycle for each parameter with peak concentrations most prevalent during the winter months of November, December and January. There were predominant increases in the concentrations during this 3-month period. This cycle is further illustrated in Figures 5.6-3a, 5.6-3b and 5.6-3c which display mean monthly maximum and monthly mean concentrations for the complete CMP cumulative annual cycle from May 6, 1989, through September 30, 1990. This is also shown in Figures 5.6-4a, 5.6-4b and 5.6-4c, which

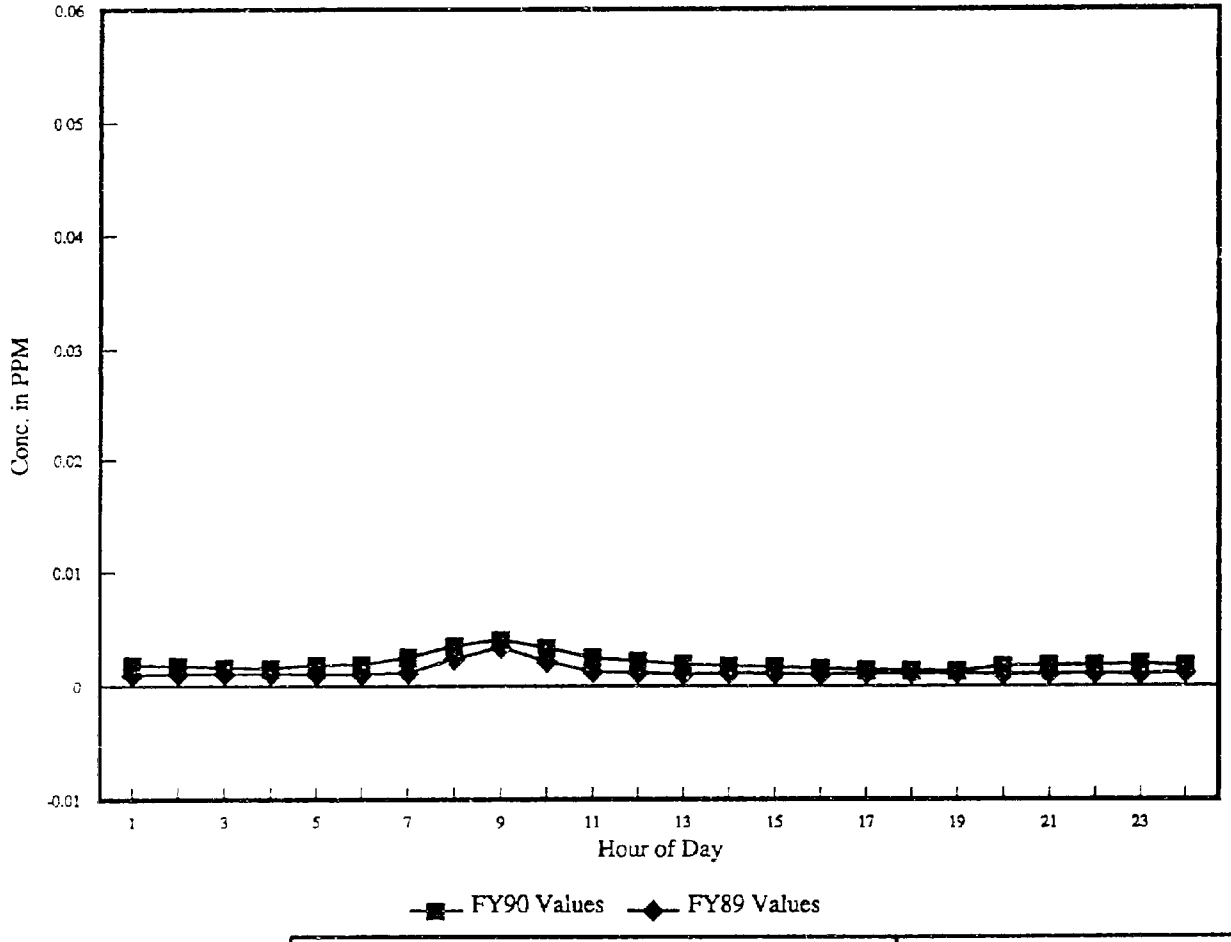

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Figure 5.5-5

Graphical Depiction of Diurnal Comparison for Sulfur Dioxide (May-September)

CMP AR FY90

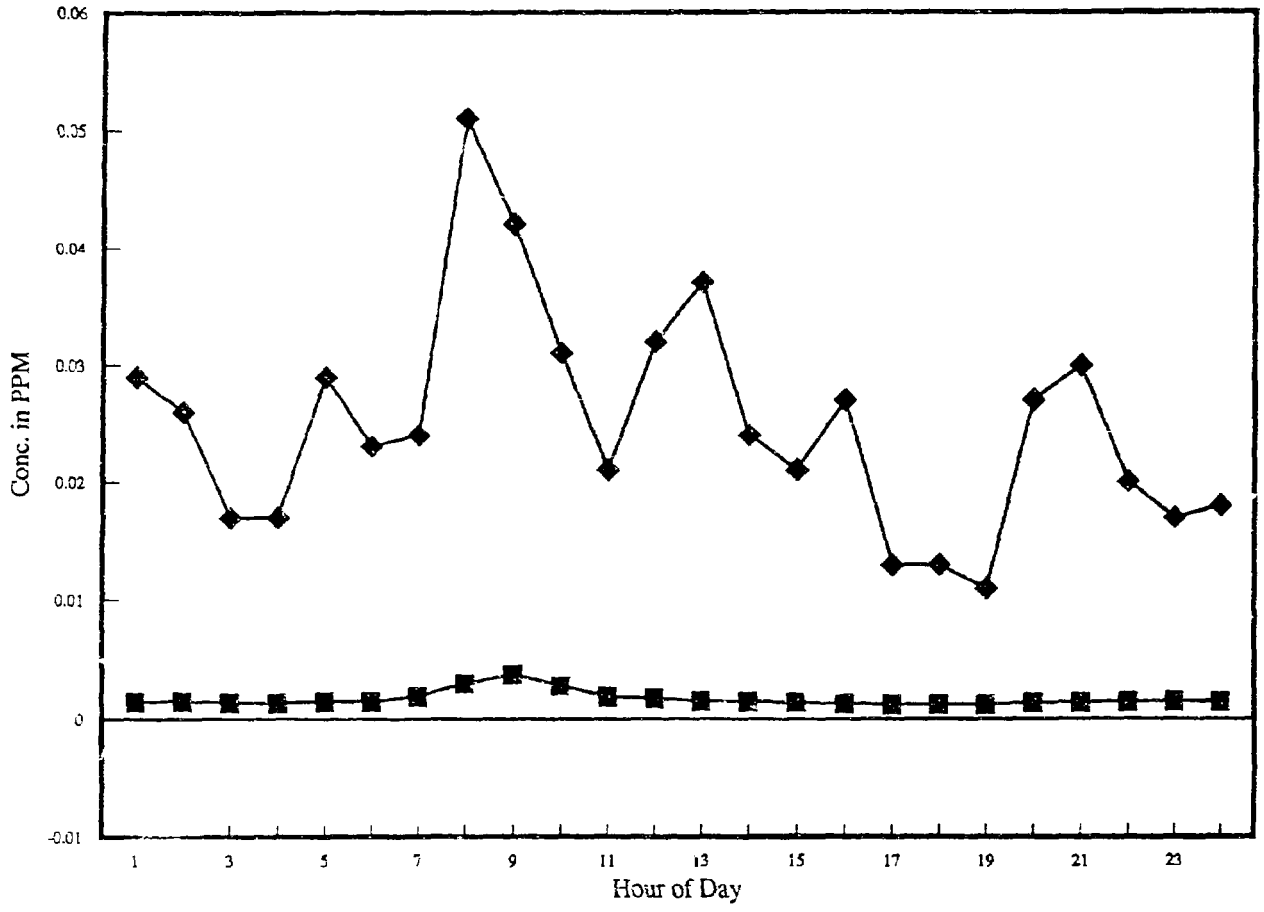

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Figure 5.5-6

Graphical Depiction of Overall Mean for Sulfur Dioxide
(May 6, 1989-September 30, 1990)

CMP AR FY90

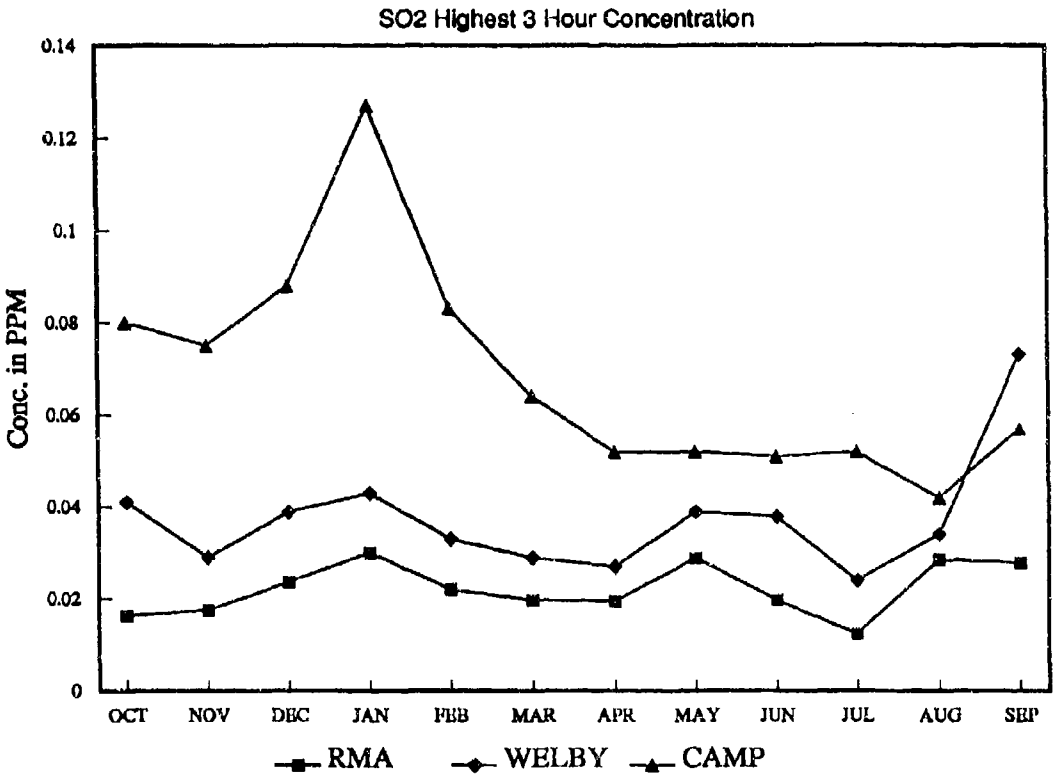

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Figure 5.5-7

CMP and Colorado Department of Health Sites 3-Hour Sulfur Dioxide Values (Oct., 1989-Sept., 1990)

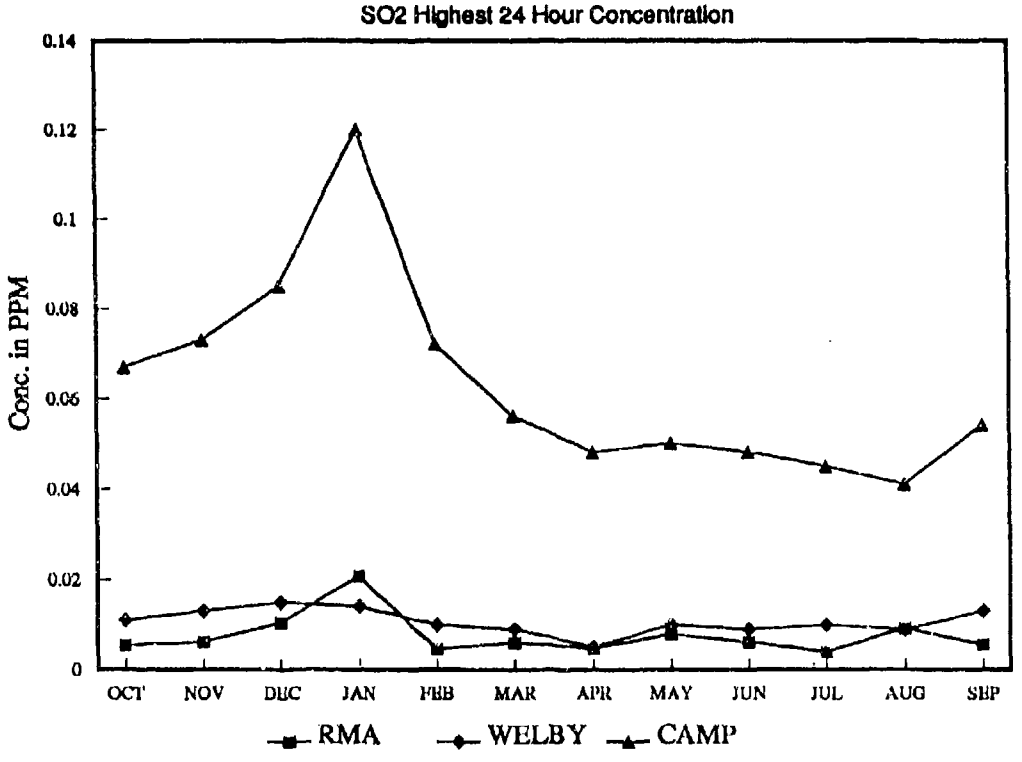

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Figure 5.5-8
CMP and Colorado Department of Health Sites 24-Hour Sulfur Dioxide Values (Oct., 1989-Sept., 1990)

CMP AR FY90

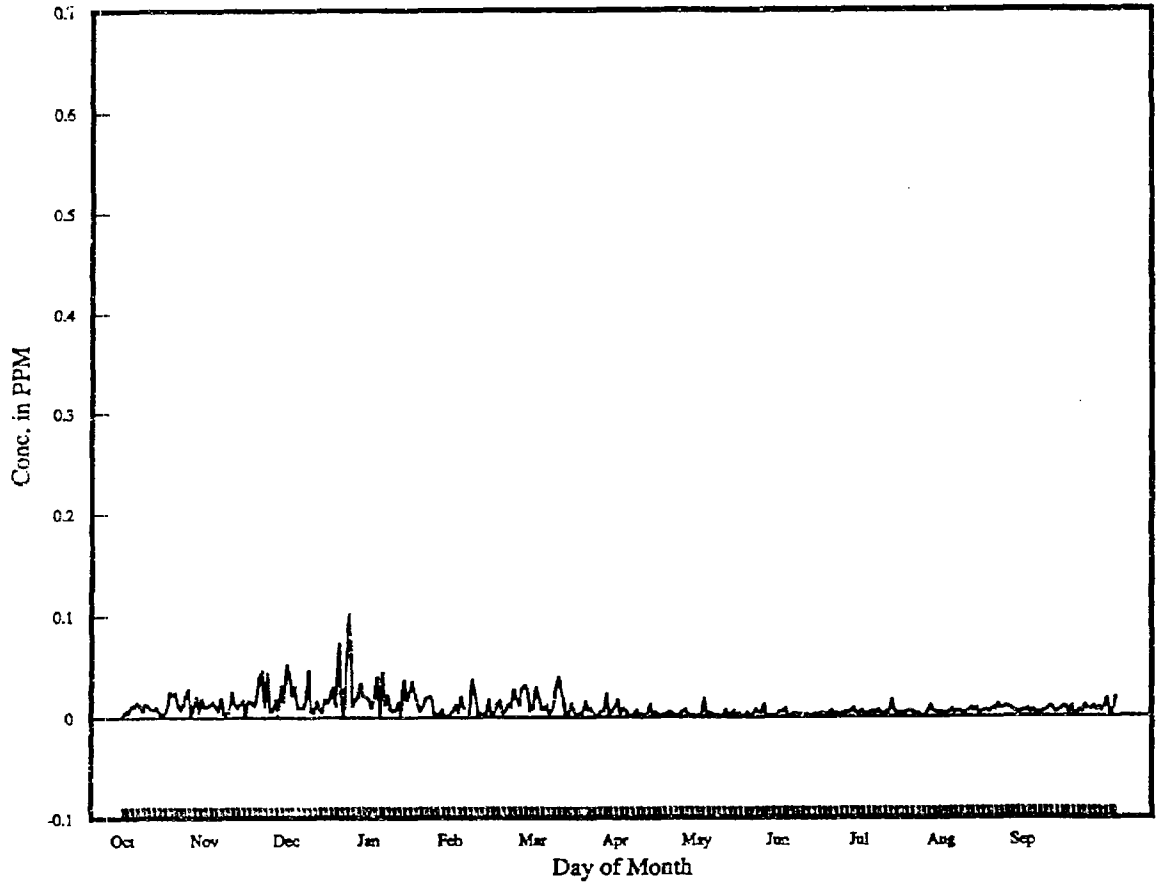

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Figure 5.6-1a
Graphical Depiction of Daily Mean for
Nitric Oxide FY90
(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

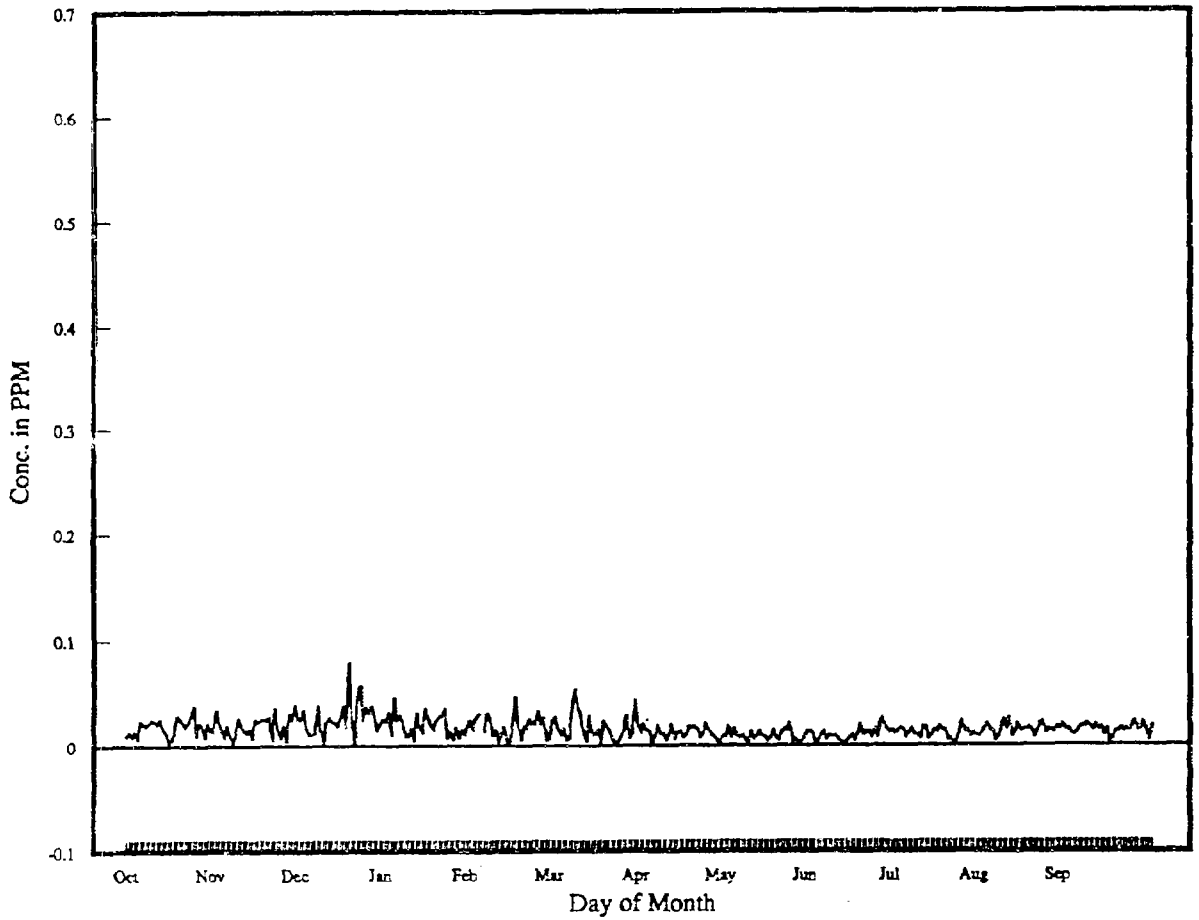

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Figure 5.6-1b

Graphical Depiction of Daily Mean for Nitrogen Dioxide FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

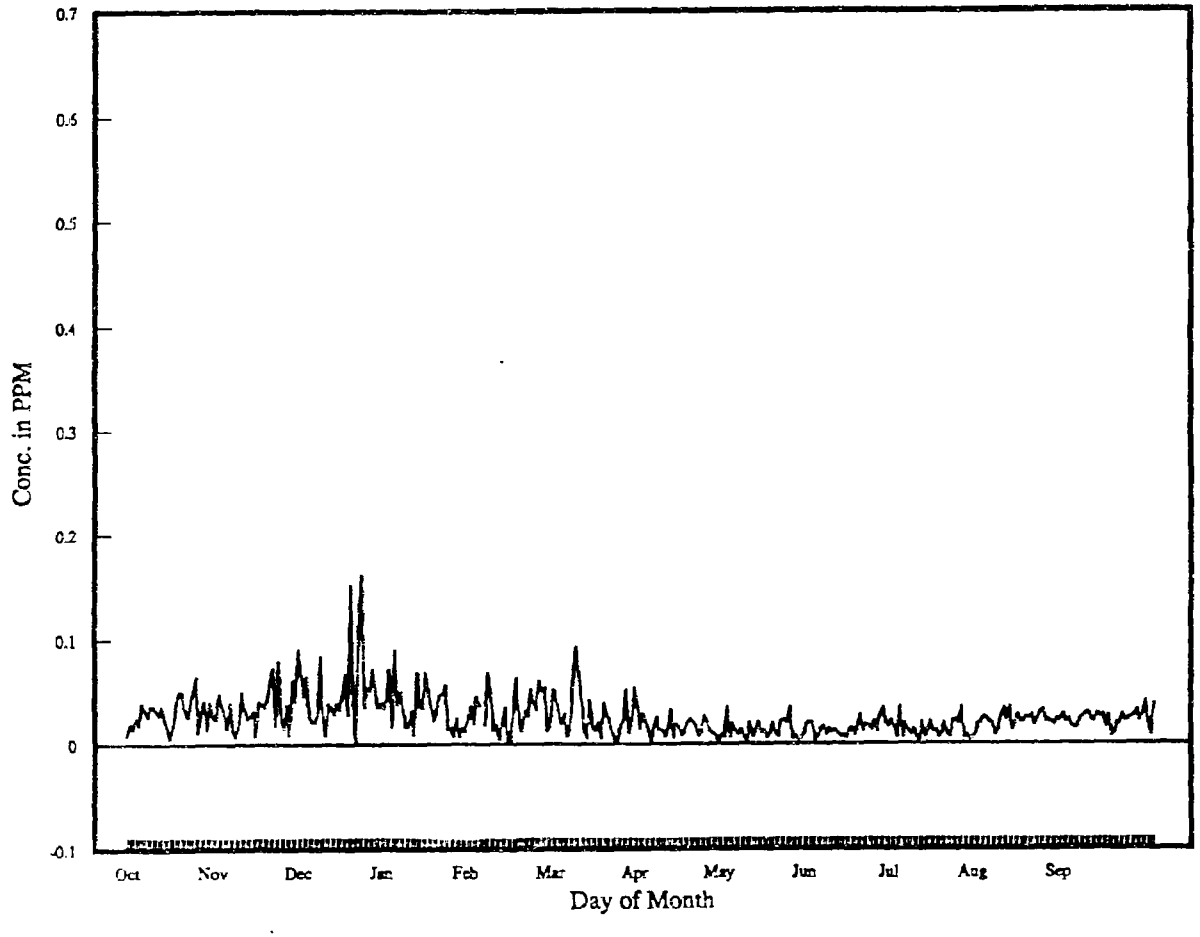

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Figure 5.6-1c
Graphical Depiction of Daily Mean for
Nitrogen Oxides FY90
(Oct., 1989- Sept. 30, 1990)
CMP AR FY90

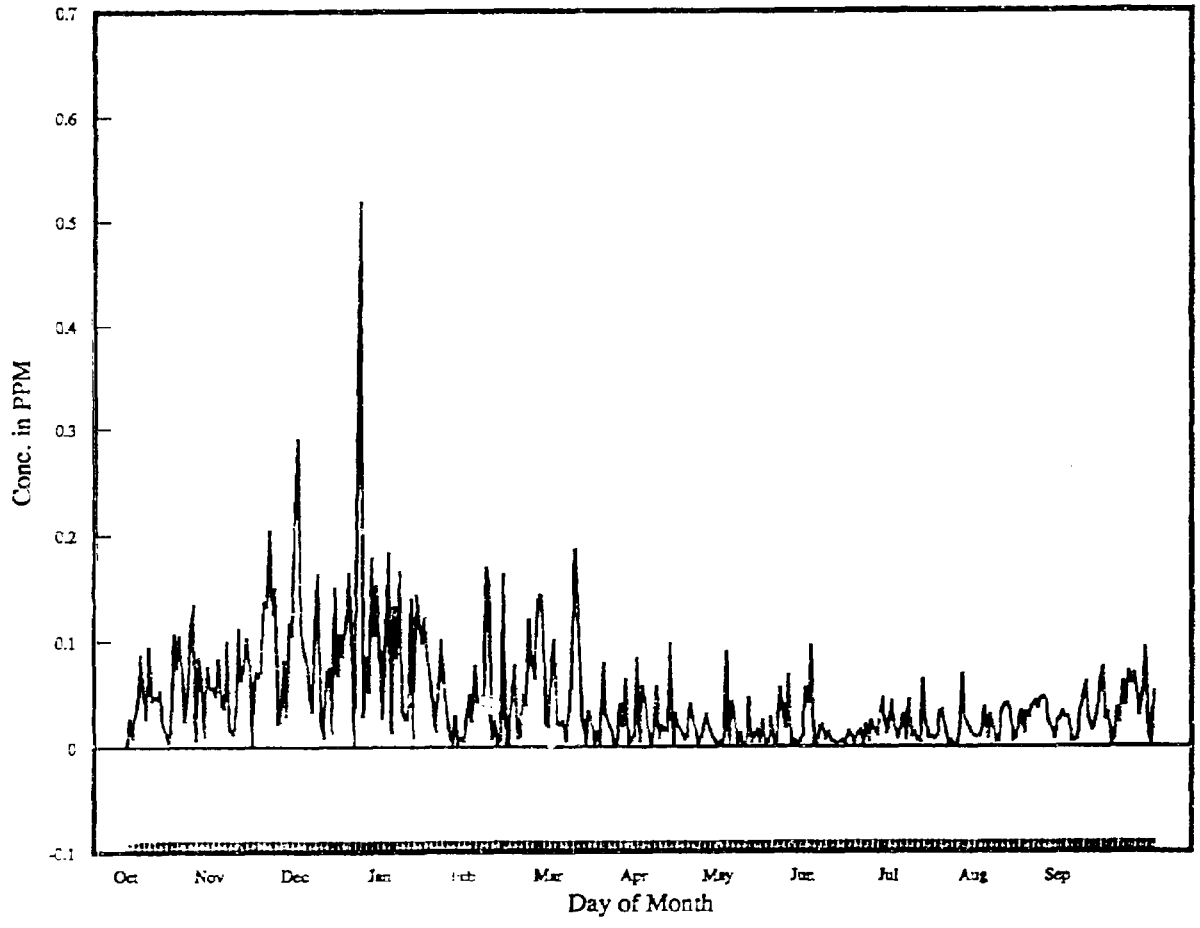

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Figure 5.6-2a
Graphical Depiction of Daily Maximum
for Nitric Oxide FY90
(Oct., 1989-Sept. 30, 1990)

CMP AR FY90

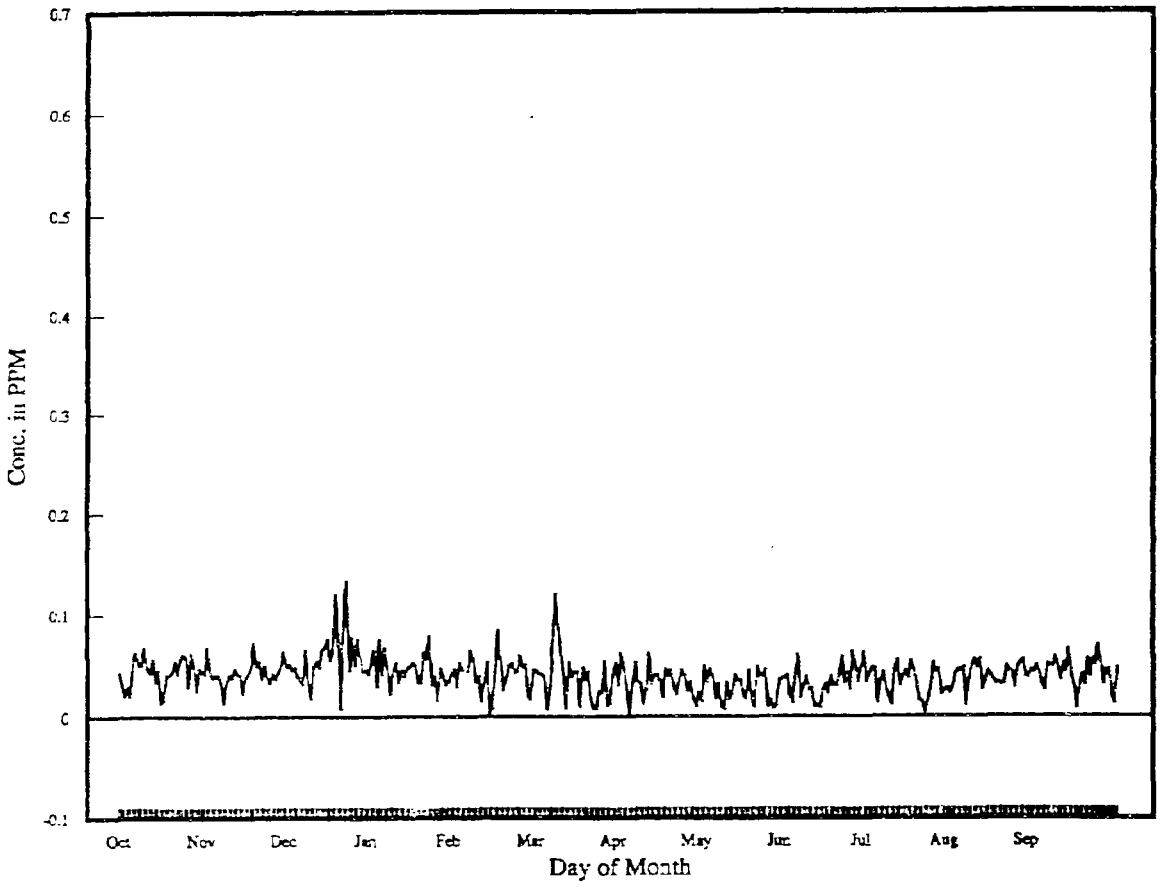

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Figure 5.6-2b

Graphical Depiction of Daily Maximum for Nitrogen Dioxide FY90 (Oct., 1989-Sept. 30, 1990)

CMP AR FY90

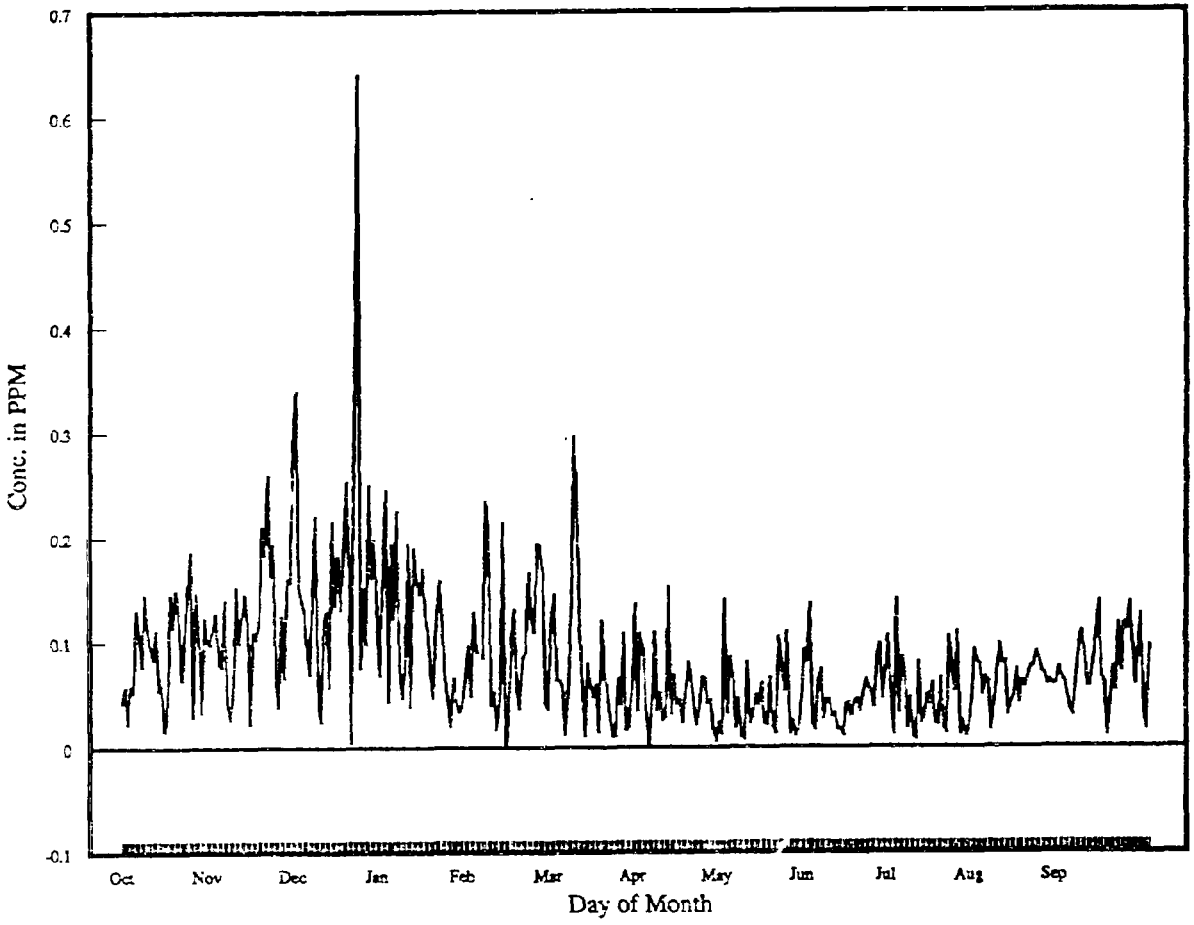

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Figure 5.6-2c

Graphical Depiction of Daily Maximum for Nitrogen Oxides FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

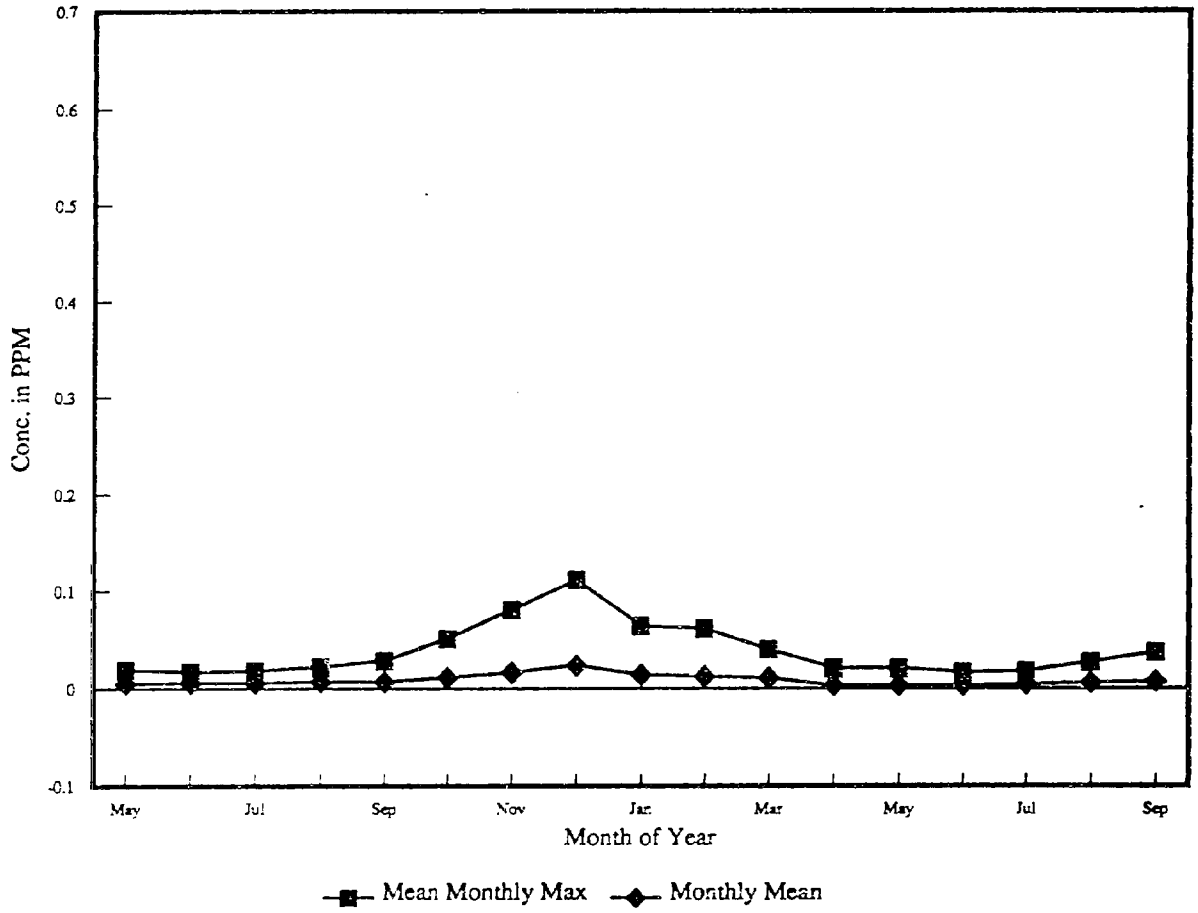

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Figure 5.6-3a

Graphical Depiction of Monthly Mean for Nitric Oxide (May, 1989-Sept., 1990)

CMP AR FY90

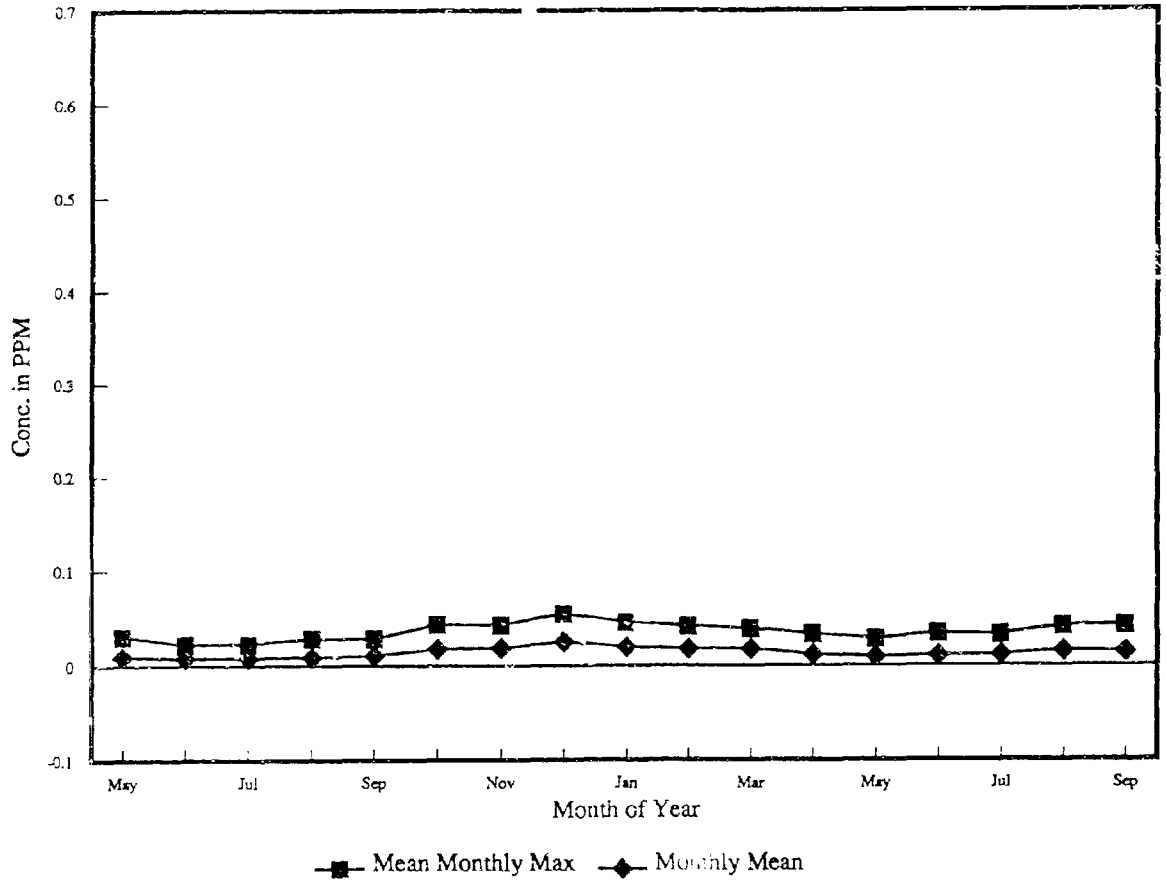

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Figure 5.3-3b

Graphical Depiction of Monthly Mean for Nitrogen Dioxide (May, 1989-Sept., 1990)

CMP AR FY90

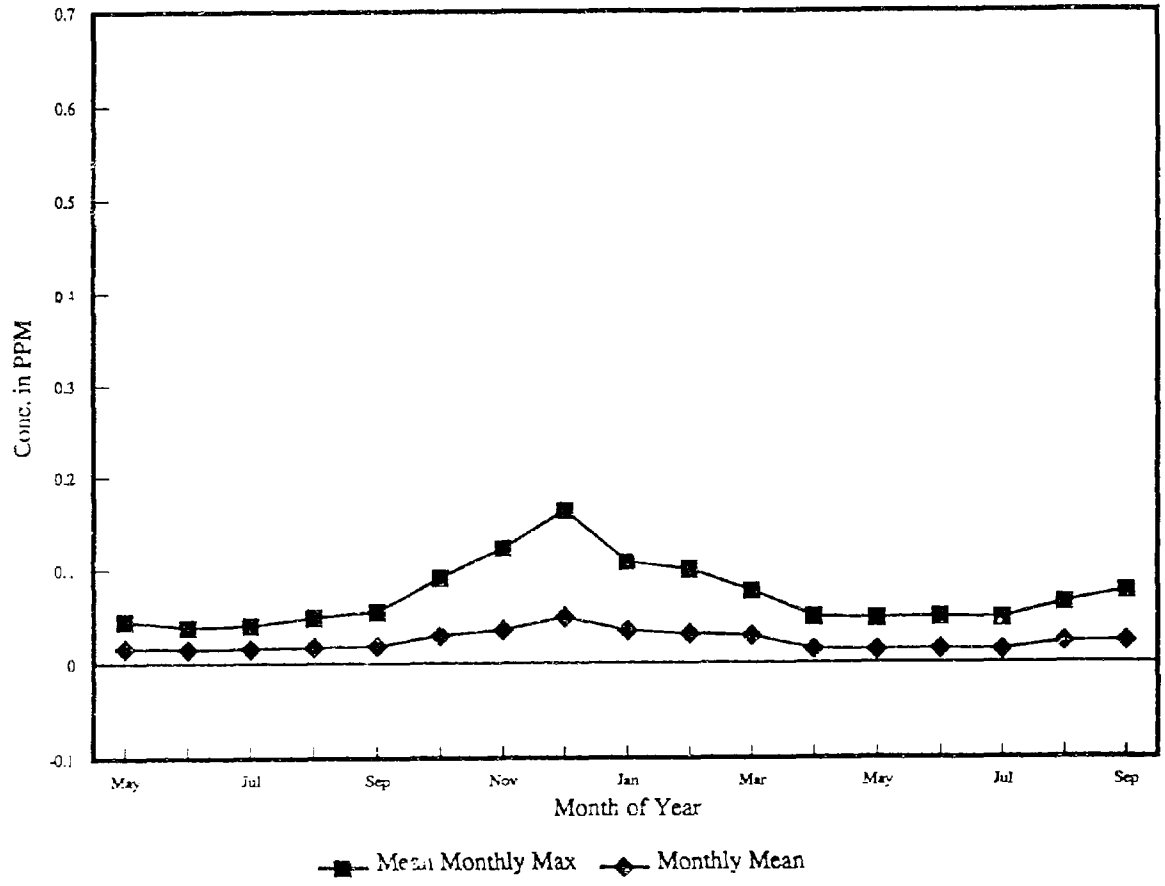

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Figure 5.6-3c

Graphical Depiction of Monthly Mean for Nitrogen Oxides (May, 1989-Sept., 1990)

CMP AR FY90

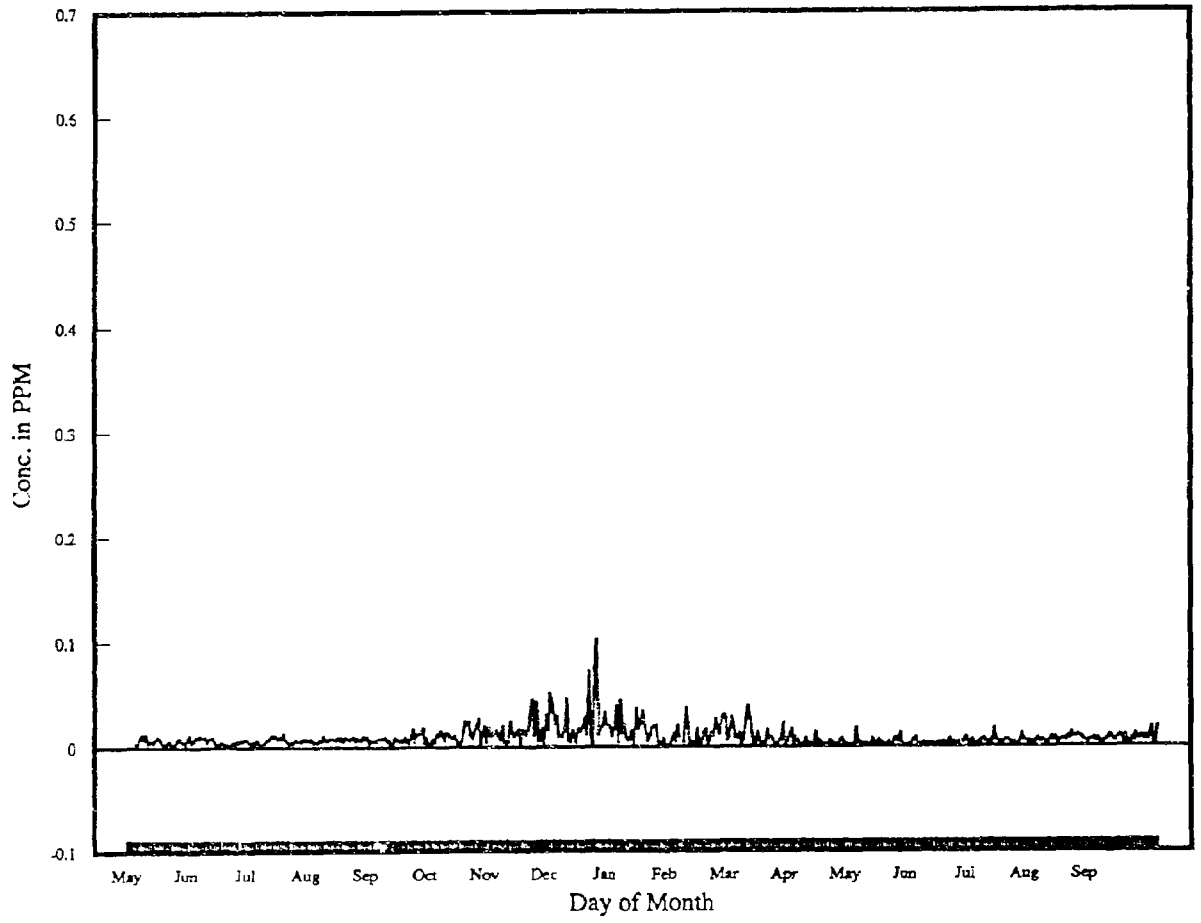

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Figure 5.6-4a

Graphical Depiction of Daily Mean for Nitric Oxide
(May 6, 1989-Sept. 30, 1990)

CMP AR FY90

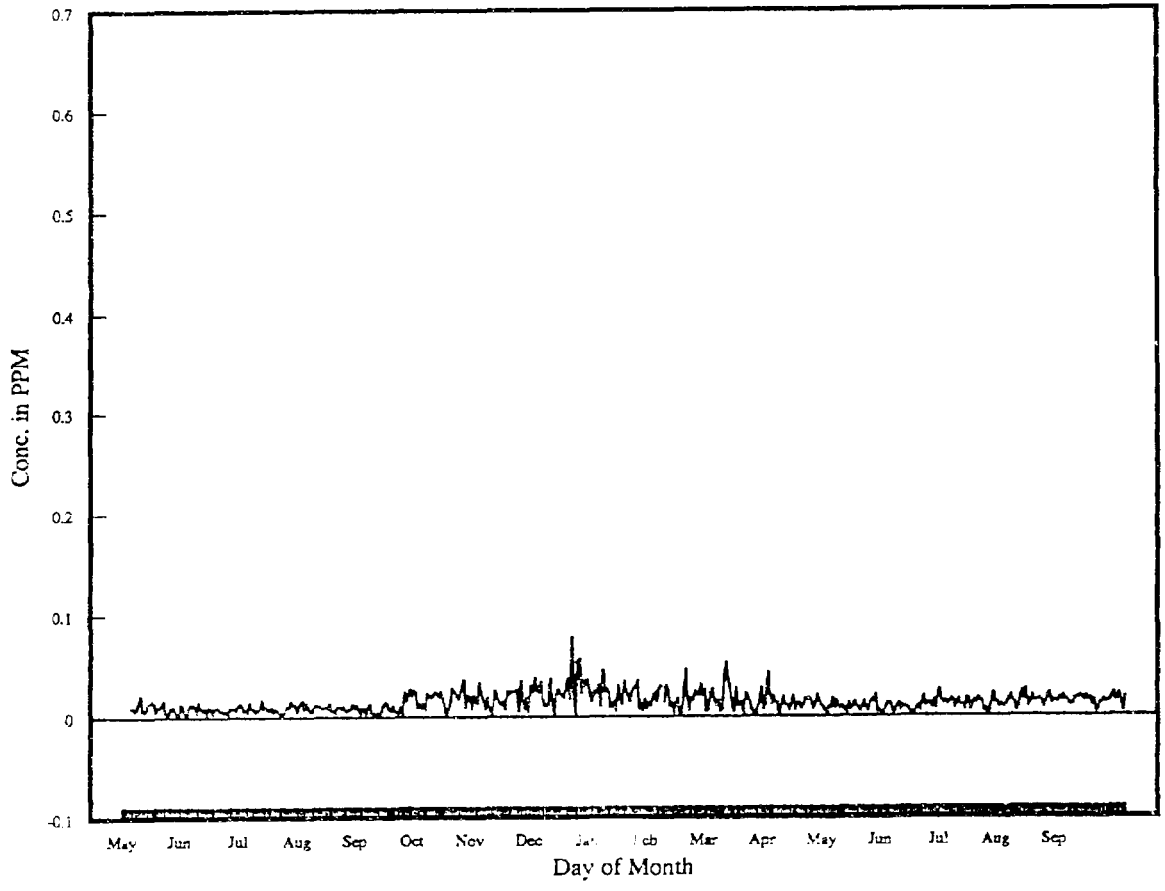

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Figure 5.6-4b
Graphical Depiction of Daily Mean
for Nitrogen Dioxide
(May 6, 1989-Sept. 30, 1990)

CMP AR FY90

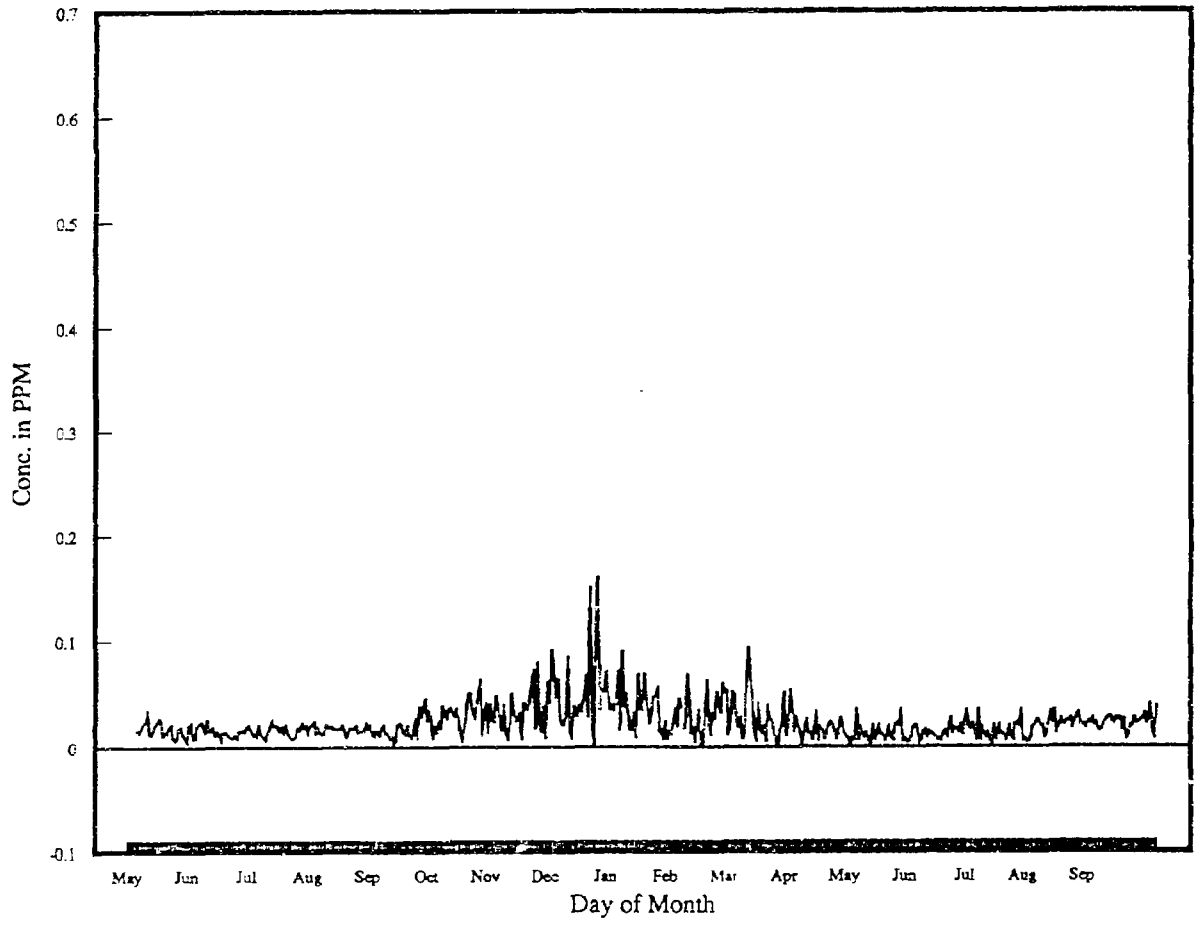

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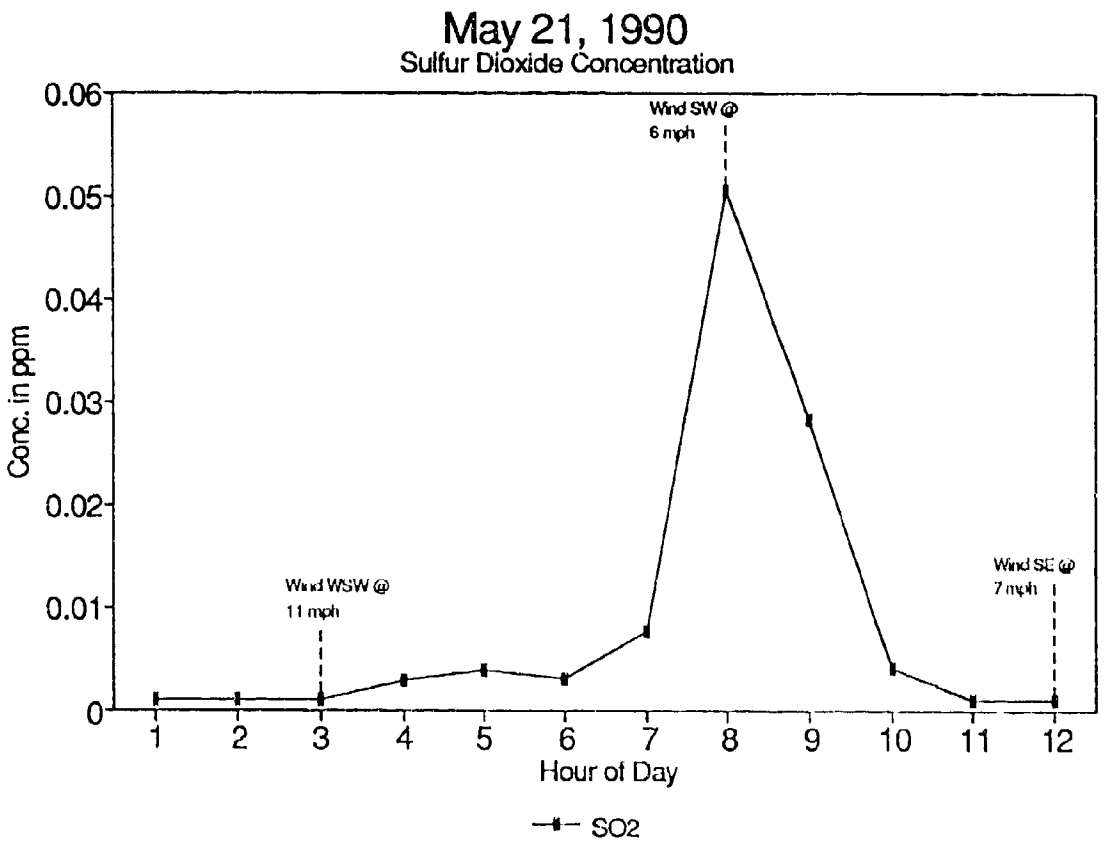
Figure 5.6-4c

Graphical Depiction of Daily Mean for Nitrogen Oxides (May 6, 1989-Sept. 30, 1990)

CMP AR FY90



Prepared for :

U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Figure 5.7-6
Graphical Depiction of
Sulfur Dioxide for
May 21, 1990

CMP AR FY90

display the daily mean concentrations. Again, these graphs indicate that higher concentrations occurred during the winter months of November, December and January.

Monthly summaries for 1-hour average concentrations of NO, NO_2 and NO_x are given in Tables 5.6-1, 5.6-2 and 5.6-3, respectively. The National Ambient Air Quality Standard for NO_2 is 0.053 ppm and is an arithmetic mean. The mean for FY90, 0.016 ppm, was well below this standard.

Since seasonal and diurnal trends of NO, NO_2 and NO_x are interrelated, an assessment of these three gases as a whole was made using NO_x as the indicator. The diurnal cycle for these gases illustrated a similar pattern with peak concentrations during the morning hours of 0700 MST and 0900 MST which coincided with the Denver metropolitan area rush hour. For the remainder of the day, these gases exhibited their lowest concentrations, although there is a slight rise again in the late evening hours, possibly from the reformation of the surface inversion. This cycle is depicted in Figure 5.6-5.

A comparison of the diurnal cycle for the data collection period of May through September for FY89 and FY90 is shown in Figure 5.6-6. The data were almost identical with a very slight increase of NO_x in FY90. Again, similar diurnal trends are displayed in these graphs.

Figure 5.6-7 depicts the overall maximum hourly concentrations and overall mean hourly concentrations for the cumulative period of May 6, 1990, through September 30, 1990. This graph indicates that the individual maximum concentrations were recorded between the hours of 2000 MST and 0400 MST and not during the morning rush hour as the diurnal pattern portrays. This may be attributed to individual episodes in which drainage and wind flow from power plants and/or other industrial activities resulted in peak concentrations at RMA during these hours. Figure 5.6-8 compares the highest 24-hour nitrogen dioxide concentrations recorded at RMA to two Colorado Department of Health sites for the period October 1989 through September 1990. The RMA site recorded lower values than the two Colorado Department of Health locations. Several case studies are discussed in the next section showing the interaction of metropolitan Denver source emissions, meteorological conditions, and ambient concentrations measured at RMA.

Individual monthly graphs and tables are presented in Appendix I. The items contain daily maximum, minimum and mean concentrations for each day of each month.

Table 5.6-1 Summary of Nitric Oxide 1-Hour Average Values in ppm October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.011	0.016	0.023	0.014	0.013	0.011
Maximum	0.134	0.247	0.518	0.183	0.169	0.186
2nd Highest Maximum	0.130	0.204	0.466	0.164	0.169	0.155
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.003	0.003	0.003	0.005	0.006	0.007
Maximum	0.097	0.089	0.095	0.068	0.047	0.093
2nd Highest Maximum	0.066	0.087	0.046	0.063	0.046	0.076
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

Mean for Entire Period 0.010

Table 5.6-2 Summary of Nitrogen Dioxide 1-Hour Average Values in ppm[1] October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.018	0.019	0.026	0.020	0.018	0.017
Maximum	0.067	0.072	0.133	0.078	0.084	0.120
2nd Highest Maximum	0.062	0.067	0.123	0.075	0.064	0.112
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.012	0.010	0.010	0.012	0.015	0.015
Maximum	0.061	0.050	0.063	0.055	0.056	0.069
2nd Highest Maximum	0.061	0.049	0.062	0.054	0.056	0.065
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

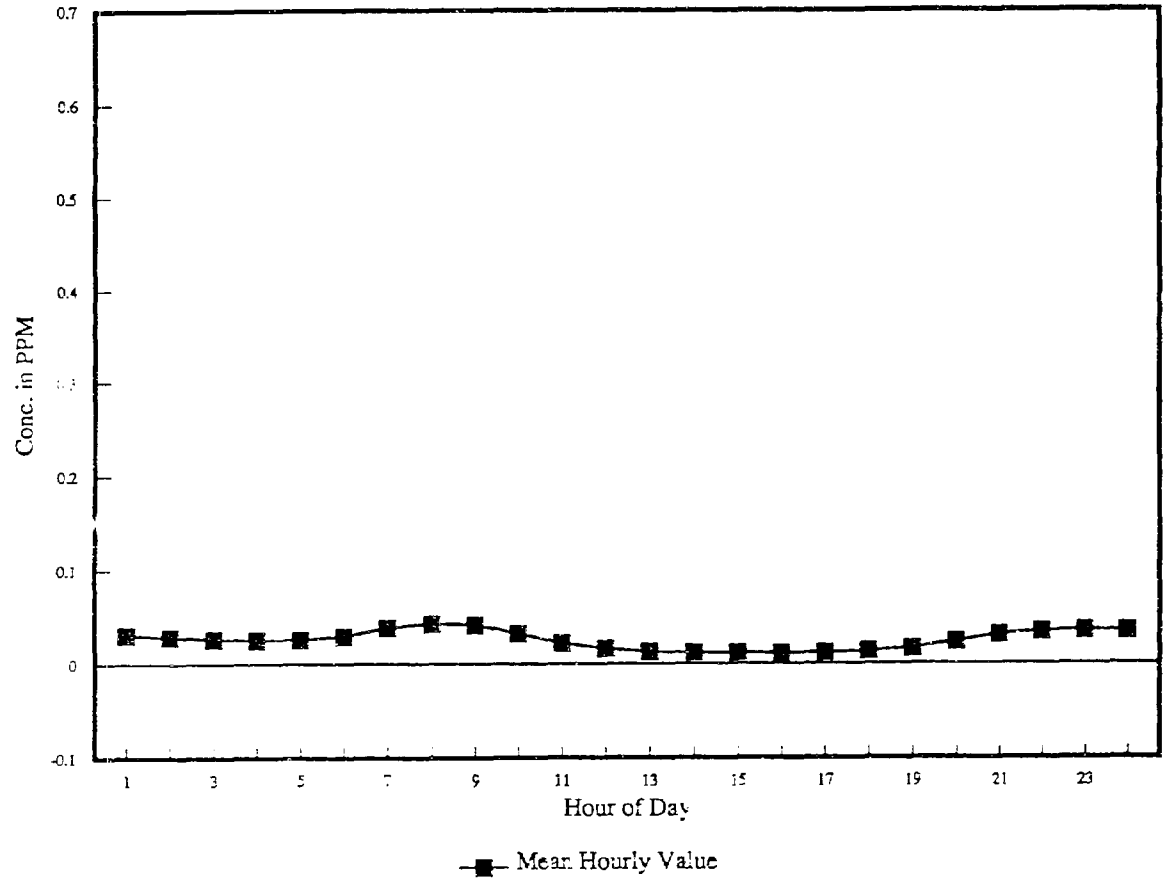
Mean for Entire Period 0.016

[1] Federal and Colorado Ambient Air Quality Standard for annual arithmetic mean is 0.053 ppm.

Table 5.6-3 Summary of Nitrogen Oxides 1-Hour Average Values in ppm October, 1, 1989 (0100 MST) through September 30, 1990 (2400 MST)

	Oct	Nov	Dec	Jan	Feb	Mar
Mean	0.029	0.036	0.050	0.034	0.031	0.028
Maximum	0.186	0.311	0.640	0.244	0.234	0.296
2nd Highest Maximum	0.184	0.259	0.601	0.225	0.229	0.266
Minimum	0.001	0.001	0.001	0.001	0.001	0.001

	Apr	May	Jun	Jul	Aug	Sep
Mean	0.015	0.013	0.014	0.017	0.022	0.023
Maximum	0.152	0.140	0.136	0.117	0.097	0.138
2nd Highest Maximum	0.129	0.128	0.105	0.102	0.090	0.137
Minimum	0.001	0.001	0.001	0.001	0.004	0.003
Mean for Entire Period	0.026					



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Prepared by :

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Ebasco Services, Inc.

Figure 5.6-5

Graphical Depiction of Diurnal Cycle for Nitrogen Oxides FY90 (Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

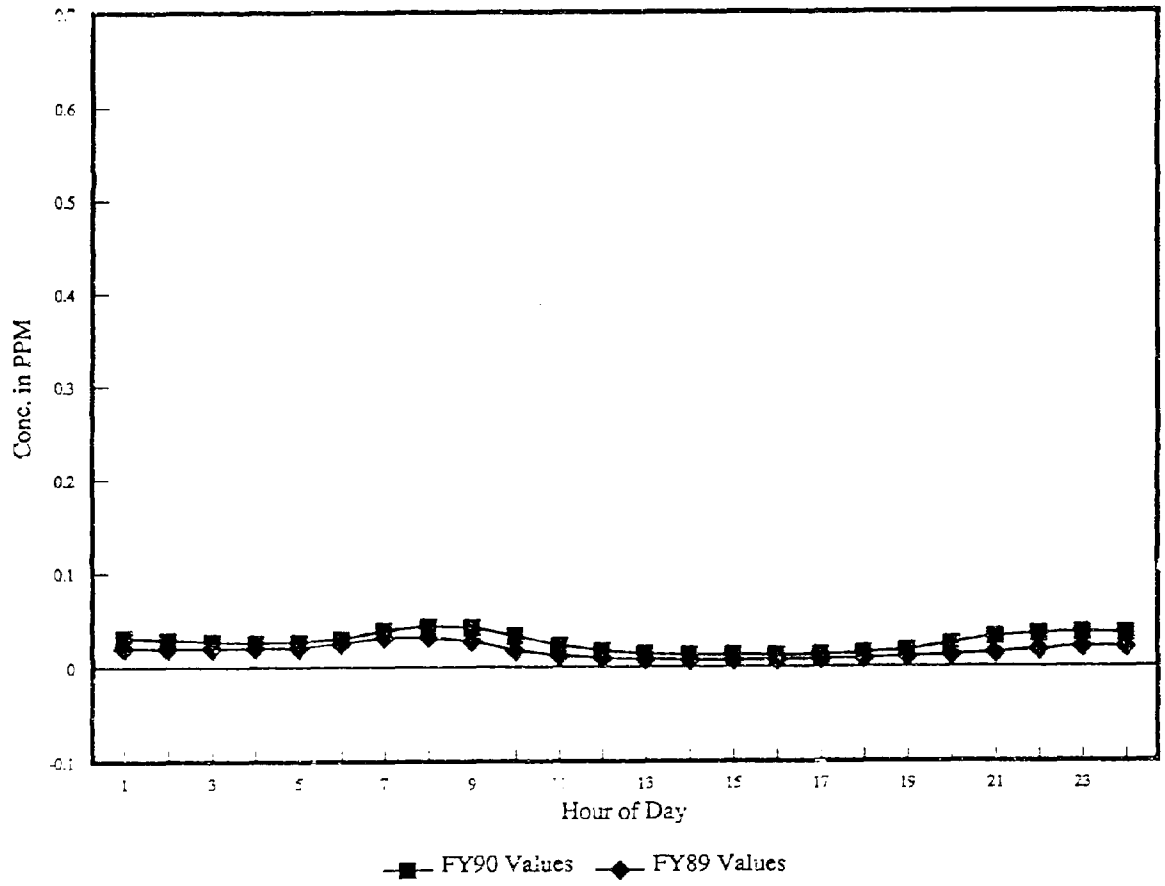

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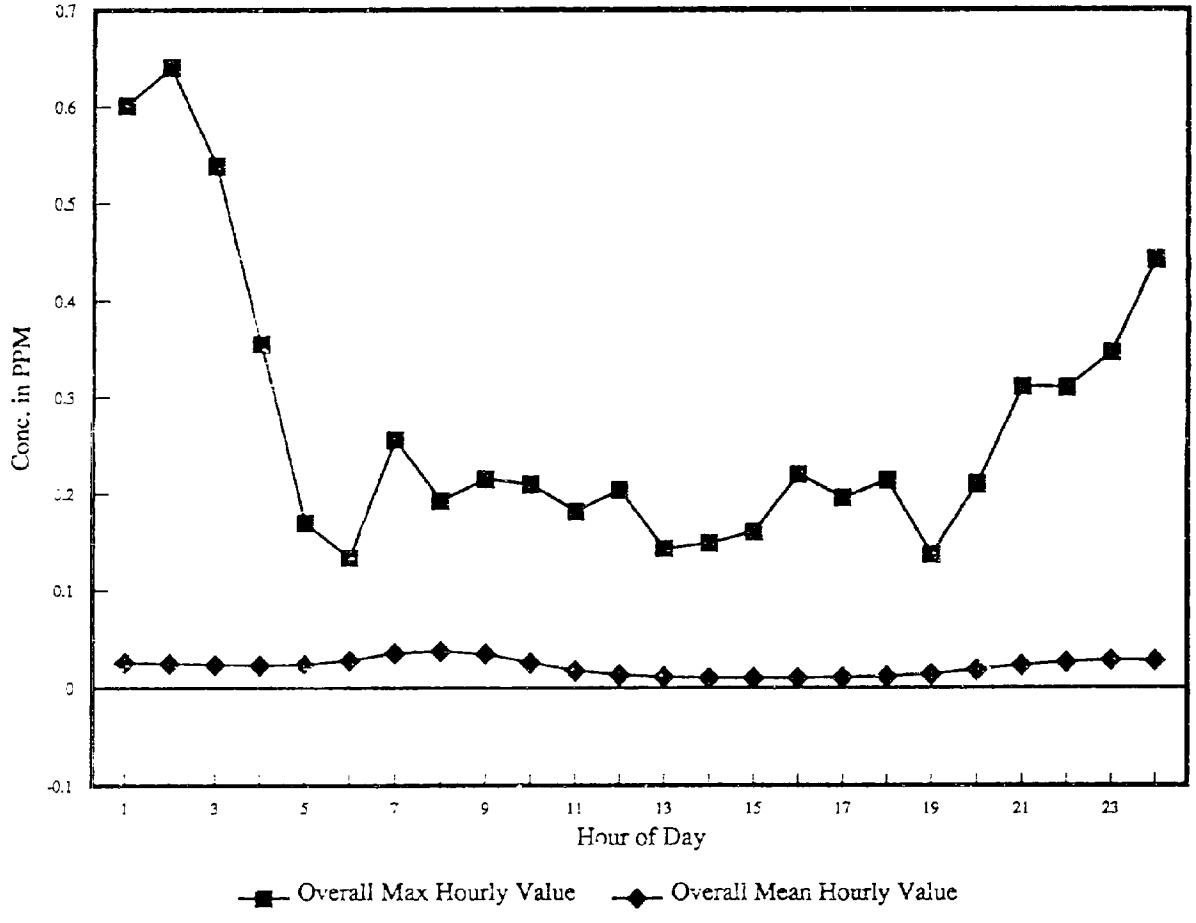
Figure 5.6-6

Graphical Depiction of Diurnal Comparison for Nitrogen Oxides (May-September)

CMP AR FY90



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Prepared by :

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Figure 5.6-7

Graphical Depiction of Diurnal Mean for Nitrogen Oxides (May 6, 1989-Sept. 30, 1990)

CMP AR FY90

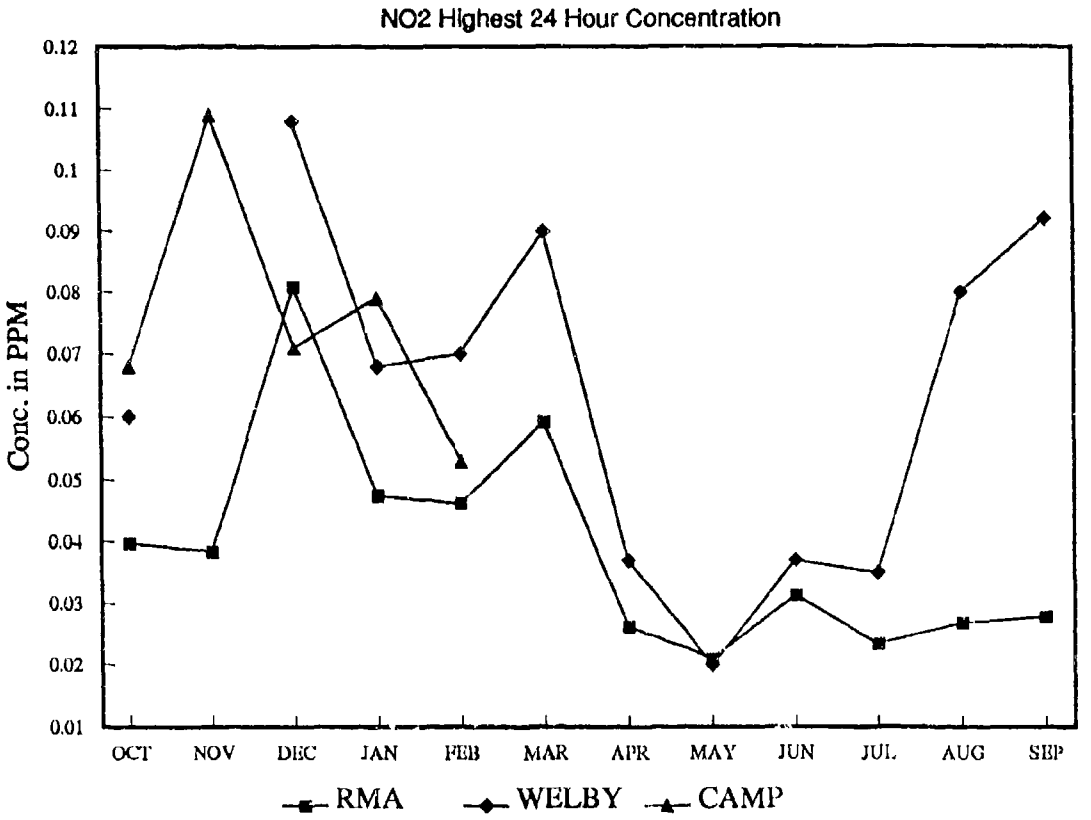

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Figure 5.6-8

CMP and Colorado Department of Health Sites 24-Hour Nitrogen Dioxide Values (Oct., 1989-Sept., 1990)

CMP AR FY90

5.7 REGIONAL EMISSION SOURCES IMPACTING RMA

Tables 5.7-1 through 5.7-3 provide listings of criteria pollutant emissions (carbon monoxide, sulfur dioxide, and nitrogen oxides) from major metropolitan Denver industrial sources. (Table 4.1-2 previously cited in Section 4.1.4 also provides a more detailed listing including many smaller sources.) Ozone (O_3) is not emitted directly from a source as are other pollutants, but forms as a secondary pollutant. Its precursors are certain reactive hydrocarbons and nitrogen oxides (NO_x). Those sources listed in Tables 5.7-1 and 5.7-3 can therefore be considered as contributors to O_3 production.

In addition to stationary sources, automobile exhaust is a principal precursor of O_3, and in the winter, produces 86 percent of the carbon monoxide (CO) measured in Denver and about 33 percent of the NO_x (CDH, 1989). Both stationary and mobile emissions (primarily from vehicle traffic) jointly contribute to the ambient air quality conditions measured at RMA. Note that RMA gaseous emissions shown in Tables 5.7-1 through 5.7-3 are quite small compared to the significant major sources in the Denver area.

Figure 5.7-1 shows the distribution of stationary sources surrounding RMA (source locations are cross-referenced in Tables 5.7-1, 5.7-2 and 5.7-3). Most of the sources are to the south and southwest of the Arsenal where the major vehicle activity also occurs. Monitoring results from the RMA station showed levels of O_3, CO, SO_2, and NO_x that were generally below metropolitan Denver monitoring values. However, when prevailing winds blew in the direction of the Arsenal with a strong inversion and the associated "brown cloud" condition, external sources significantly impacted the Arsenal. This was demonstrated in the Air Quality Data Assessment Report for FY89 (Stollar, 1990) and is again shown with examples from the most recent FY90 visibility and gaseous monitoring data.

A review of the air quality and meteorological data for RMA during FY90 indicates a number of episodes of probable pollution migration onto the Arsenal. Case studies for TSP, PM-10, metals and VOCs have been discussed in prior sections of this report. Emphasis in this section is placed on criteria gaseous pollutants. As noted, in the Tri-County area of Adams, Arapahoe and Denver Counties, there were a number of NO_x, CO and SO_2 point sources and mobile sources that contributed to the RMA baseline air quality. By far, the poorest air quality days at the Arsenal, as was the case of metropolitan Denver, were associated with the existence of intense ground-level inversions over the area and the subsequent development of the so-called "brown cloud" phenomenon. When this layer of industrial haze, or pollution, drifted over the Arsenal, either directly or circuitously (after

Table 5.7-1 Carbon Monoxide (CO) Sources with Emissions of 100 TPY or More

County	UTM/E	UTM/N	Map Number	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Adams	504.7	4405.8	7	Colorado Refining Co.	824	31.9	3.8
Adams	503.0	4406.2	1	PSCO Cherokee Plant	500	19.3	2.3
Adams	509.5	4429.5	29	Vessels Oil and Gas	257	9.9	1.2
Adams	504.5	4405.5	4	Conoco Inc.	240	9.3	1.1
Adams	524.7	4400.5	3	Colorado Interstate Gas	162	6.3	0.8
Adams	503.8	4406.5	13	Metro Denver Sewage Disp.	145	5.6	0.7
Adams	513.6	4408.3	30	RMA	7	0.3	
TRI-COUNTY TOTALS					2586	72.4	
STATE TOTALS					21534		8.7

Source: Colorado Department of Health EISPS Inventory, May 1990.

Table 5.7-2 Sulfur Dioxide (SO2) Sources with Emissions of 40 TPY or More

County	UTM/E	UTM/N	Map #	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Adams	503.0	4406.2	1	PSCO Cherokee Plant	11753	67.8	12.9
Adams	504.5	4405.5	4	Conoco Inc.	2182	12.6	2.4
Denver	499.8	4390.9	2	PSCO Arapahoe Plant	1511	8.7	1.7
Adams	504.7	4405.8	7	Colorado Refining Company	1181	6.8	1.3
Arapahoe	500.5	4391.5	26	Littleton/Englewood	262	1.5	0.3
Denver	500.6	4399.1	10	The Gates Rubber Co.	76	0.4	0.1
Adams	504.0	4405.0	27	Republic Paper Board Co.	54	0.3	0.1
Denver	503.5	4403.1	28	Ralston Purina Co.	51	0.3	0.1
Adams	513.6	4408.3	30	RMA	5		
TRI-COUNTY TOTALS					17341	98.4	
STATE TOTALS					90868		18.8

Source: Colorado Department of Health EISPS Inventory, May 1990.

Table 5.7-3 Nitrogen Oxides (NOX) Sources with Emissions of 40 TPY or More

County	UTM/E	UTM/N	Map #	Plant Name	Emissions (tpy)	Percent Tri-County Total	Percent of State Total
Adams	503.0	4406.2	1	PSCO Cherokee Plant	14731	62.5	9.6
Denver	499.8	4390.9	2	PSCO Arapahoe Plant	3098	13.2	2.0
Adams	524.7	4400.5	3	Colorado Interstate Gas	718	3.0	0.5
Adams	504.5	4405.5	4	Conoco Inc.	567	2.4	0.4
Adams	525.1	4414.8	5	Koch Hydrocarbon Co.	454	1.9	0.3
Adams	526.1	4399.8	6	Amoco Production Co. Wat.	407	1.7	0.3
Adams	504.7	4405.8	7	Colorado Refining Co.	382	1.6	0.2
Arapahoe	506.6	4390.2	8	Amoco Production Co. Byrs	373	1.6	0.2
Adams	509.5	4429.5	29	Vessels Oil and Gas	310	1.3	0.2
Arapahoe	520.0	4395.6	9	US Govt. Buckley Air Base	290	1.2	0.2
Denver	500.6	4399.1	10	The Gates Rubber Co.	275	1.2	0.2
Denver	498.6	4398.4	11	PSCO Zuni Plant	219	0.9	0.1
Arapahoe	570.6	4384.2	12	Colorado Interstate Gas	211	0.9	0.1
Adams	503.8	4406.5	13	Metro Denver Sewage Disp.	130	0.6	0.1
Adams	499.7	4406.9	14	Western Paving Constr.	126	0.5	0.1
Arapahoe	555.4	4388.0	15	Sun Gas Dragoon Compress	24	0.5	0.1
Adams	502.0	4417.0	16	US West	116	0.5	0.1
Adams	532.0	4415.0	17	Amoco Production 3rd Cr.	117	0.5	0.1
Arapahoe	541.0	4394.0	18	Gulf Energy Development	96	0.4	0.1
Adams	551.7	4414.8	19	Koch Hydrocarbon Co.	80	0.3	0.1
Adams	516.0	4427.6	20	Panhandle East. Pipeline	75	0.3	
Adams	530.8	4414.9	21	Koch Hydrocarbon Co.	73	0.3	
Denver	509.5	4397.0	22	Lowry Air Force Base	55	0.2	
Adams	539.8	4409.2	23	Koch Hydrocarbon Co.	54	0.2	
Adams	501.2	4406.4	24	ITT Continental Baking	47	0.2	
Denver	500.1	4400.4	25	PSCO Delgany Plant	41	0.2	
Adams	513.6	4408.3	30	RMA	25	0.1	
TRI-COUNTY TOTALS					23551	98.2	
STATE TOTALS					153913		14.8

Source: Colorado Department of Health EISPS Inventory, May 1990.

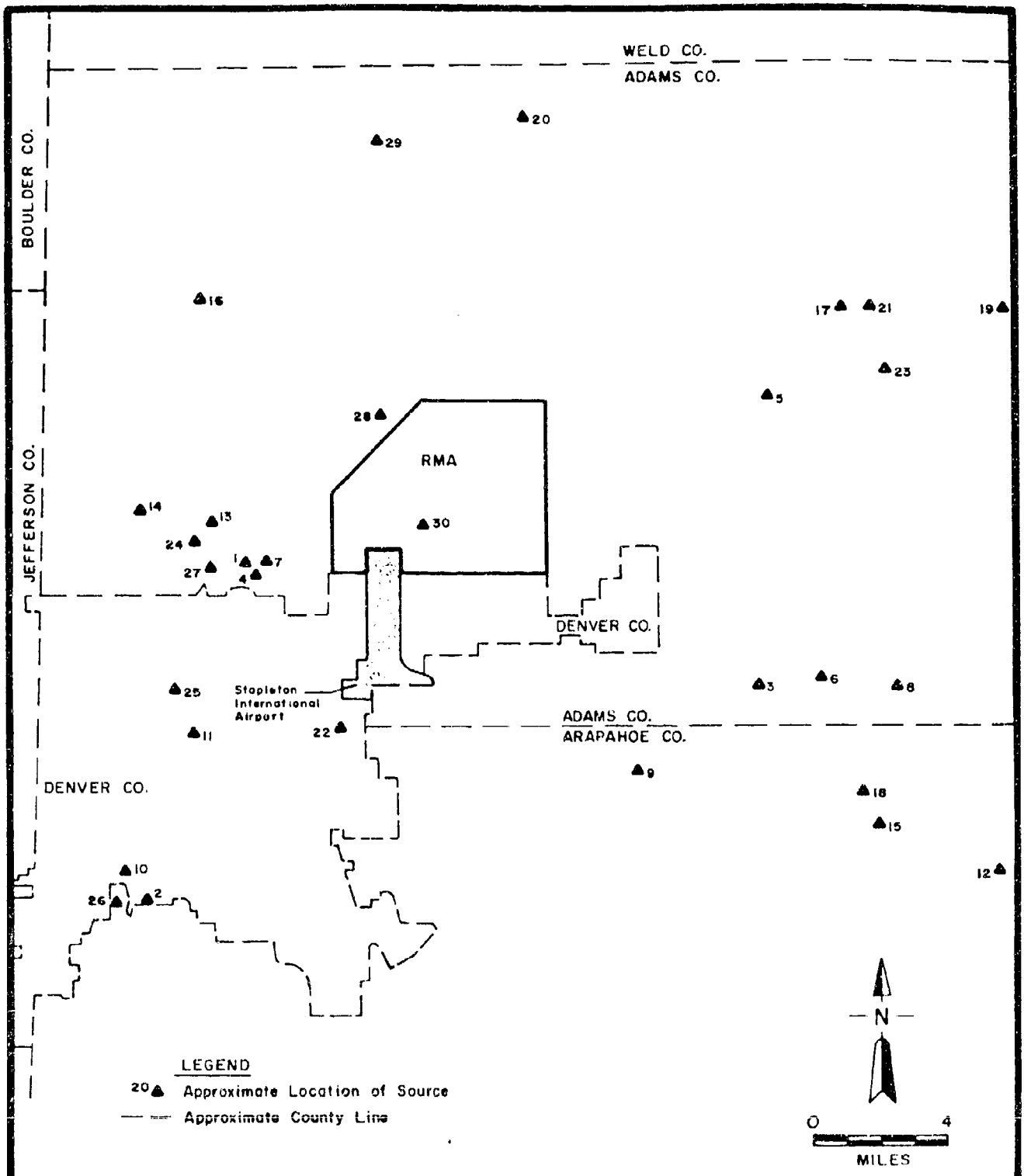

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Figure 5.7-1

Sources of Regulated Pollutants in RMA Vicinity

(See Tables 5.7-1, 5.7-2, 5.7-3 for Source Reference)

a wind shift), RMA recorded its highest levels for almost all pollutants measured. In the case of TSP, PM-10, metals, VOCs and SVOCs, it was necessary to distinguish between potential local RMA sources and external sources. However, since emissions of criteria gaseous pollutants were minimal on the Arsenal, a clear record of these incursions was provided by the meteorological and gaseous monitored data collected at the Arsenal. Some examples are illustrated below.

5.7.1 DECEMBER 22-23, 1989

During the period of December 22, 1989, at 0100 MST through December 23, 1989, at 1600 MST, RMA recorded some of the highest yearly 1-hour concentrations of carbon monoxide (CO), nitric oxide (NO), nitrogen dioxide (NO_2) and nitrogen oxides (NO_x). At 0200 MST on December 23, 1989, hourly concentrations of CO, NO and NO_x were 8.47 ppm, 0.518 ppm and 0.640 ppm respectively. The FY90 1-hour maximum for NO_2 at RMA, 0.133 ppm, was recorded at 0100 MST on the same day. Table 5.7-4 presents pertinent data for this time period.

Meteorological conditions present during this episode are also shown in Table 5.7-4. It is evident that a very cold system dominated the Denver metropolitan area during this period. A review of meteorological conditions on December 22, 1989, revealed subzero temperatures for several hours preceding the advent of the high pollution readings. The minimum temperature recorded was -14°F at 4 a.m. These very cold temperatures were the precursor to a strong and very defined surface inversion. This inversion weakened for a few hours during midday on December 22, 1989, but was reinforced later that day in the early evening and did not break until mid-morning on December 23, 1989. The positive temperature differences shown in Table 5.7-4 indicate the presence of an inversion. Also supporting the strength of this inversion were the light wind speeds of less than 5 miles per hour (mph) and the atmospheric stability classifications of E to F, stable to extremely stable conditions. (This was calculated from "sigma theta" criteria, not shown in Table 5.7-4.) This meant that there were no mechanisms to disperse the high concentrations of pollutants from the cold, stagnant air mass encompassing the Denver metropolitan area and RMA. As a result, the concentrations of these pollutants continued to rise as recorded by the RMA monitoring site.

During this 40-hour period, there were two noticeable episodes of elevated NO_x and CO concentrations, one on December 22, 1989, from 0700 MST to 1200 MST, and the other on December 22 1989, from 1900 MST through December 23, 1989, at 0800 MST. During the first period, the wind direction for this 5 hour period was mainly southerly, approximately 180° to 210°. The wind speeds were very light, less than 3 mph and there were very stable conditions in the atmosphere (i.e.

Table 5.7-4 Relevant Air Quality and Meteorological Data for December 22-23, 1989

Calendar Month	Day	Hour MST	CO ppm	SO2 ppm	NO ppm	NO2 ppm	NO_x ppm	Speed mph	Direction deg	Temp deg F	(10m-2m)* deg F
12	22	100	0.905	0.001	0.001	0.008	0.004	5.0	151	-11.5	2.3
12	22	200	0.892	0.001	0.001	0.005	0.001	4.7	13	-13.2	3.0
12	22	300	0.922	0.001	0.001	0.009	0.005	3.7	32	-13.5	2.1
12	22	400	0.976	0.001	0.001	0.013	0.009	1.8	42	-14.0	2.5
12	22	500	0.973	0.001	0.001	0.013	0.009	1.8	171	-13.9	4.9
12	22	600	1.047	0.001	0.001	0.023	0.020	1.5	191	-12.7	3.9
12	22	700	1.096	0.001	0.001	0.025	0.025	1.6	205	-12.4	4.7
12	22	800	2.335	0.003	0.081	0.047	0.130	2.5	175	-12.2	8.7
12	22	900	3.814	0.005	0.148	0.055	0.204	2.8	173	-9.7	1.8
12	22	[illegible]	4.239	0.006	0.136	0.069	0.207	1.1	161	-2.6	0.3
12	22	1100	3.055	0.006	0.078	0.062	0.141	1.1	242	4.8	0.3
12	22	1200	2.867	0.006	0.062	0.071	0.134	3.0	10	5.7	0.4
12	22	1300	2.731	CAL	CAL	CAL	CAL	4.7	46	4.9	0.0
12	22	1400	2.106	CAL	CAL	CAL	CAL	5.2	32	5.9	-0.3
12	22	1500	CAL	0.009	0.043	0.056	0.101	7.5	14	3.9	-0.4
12	22	1600	1.940	0.010	0.034	0.064	0.098	5.1	18	3.0	-0.2
12	22	1700	1.984	0.010	0.030	0.076	0.107	5.2	8	-0.6	1.2
12	22	1800	2.003	0.009	0.037	0.076	0.114	4.3	352	-2.4	2.5
12	22	1900	1.861	0.009	0.029	0.071	0.101	2.2	88	-3.1	2.7
12	22	2000	1.845	0.007	0.023	0.068	0.092	4.1	178	-2.2	4.7
12	22	2100	2.976	0.008	0.108	0.073	0.182	4.7	200	0.6	6.0
12	22	2200	4.404	0.013	0.216	0.093	0.310	2.2	236	1.2	5.0
12	22	2300	4.781	0.017	0.246	0.100	0 347	2.9	230	2.5	5.8
12	22	2400	5.950	0.018	0.329	0.112	0.442	4.2	223	3.8	5.4
12	23	100	7.740	0.025	0.466	0.133	0.601	3.2	223	5.8	4.5
12	23	200	8.470	0.024	0.518	0.120	0.640	3.4	233	7.3	4.2
12	23	300	7.650	0.016	0.415	0.123	0.539	5.0	192	9.1	4.8
12	23	400	5.517	0.009	0.265	0.090	0.356	6.6	190	12.9	3.9
12	23	500	3.108	0.003	0.108	0.061	0.170	8.3	207	17.7	4.8
12	23	600	1.979	0.003	0.043	0.051	0.095	6.4	219	20.1	6.2
12	23	700	3.900	0.008	0.174	0.081	0.256	3.4	269	18.2	5.1
12	23	800	3.280	0.009	0.114	0.073	0.188	5.8	32	13.7	1.7
12	23	900	1.811	0.004	0.031	0.040	0.072	3.0	24	19.1	-0.3
12	23	1000	1.750	0.005	0.031	0.039	0.071	3.3	158	25.8	CAL
12	23	1100	2.862	0.005	0.056	0.076	0.133	2.6	152	37.3	CAL

AIR-TBL2.90

Table 5.7-4 Relevant Air Quality and Metecrolcgical Data for December 22-23, 1989 (continued)

Calendar Month	Day	Hour MST	CO ppm	SO2 ppm	NO ppm	NO2 ppm	NO_x ppm	Speed mph	Direction deg	Temp deg F	(10m-2m)* deg F
12	23	1200	2.488	0.004	0.043	0.073	0.117	2.4	189	43.9	0.3
12	23	1300	2.339	0.009	0.050	0.081	0.132	3.8	341	38.9	-0.1
12	23	1400	2.483	0.011	0.032	0.096	0.129	3.6	224	41.4	1.4
12	23	1500	1.765	0.006	0.013	0.046	0.060	7.0	266	47.7	1.4
12	23	1600	1.675	0.003	0.009	0.043	0.053	7.1	337	50.3	0.9

NOTE: CAL denotes when a claibration was being conducted for specified parameter

* It is noted that this is a very low level stability indicator reflecting near surface conditions. It may not always relect upper atmospheric conditions.

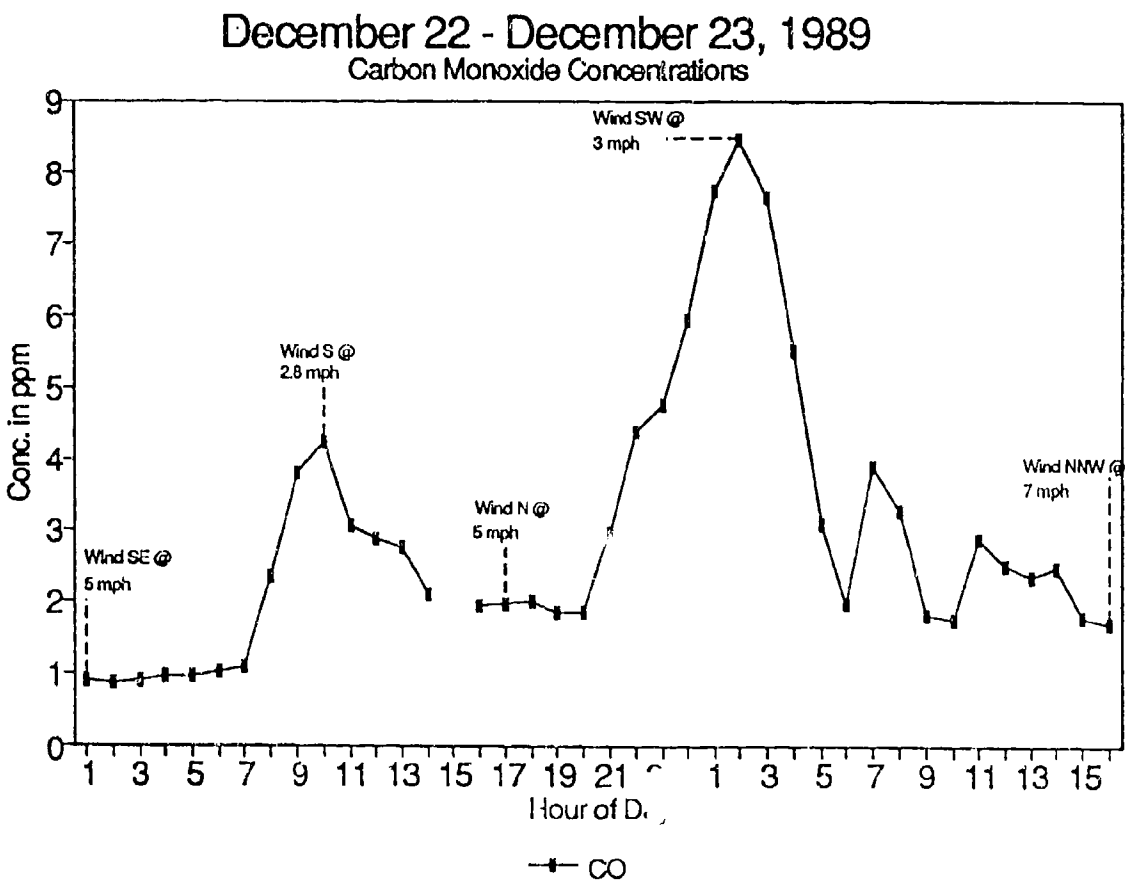
little or no mixing). Figures 5.7-2, 5.7-3 and 5.7-4 depict peak concentrations at the RMA monitoring site for this event for carbon monoxide, sulfur dioxide and oxides of nitrogen, respectively. Possible causes for the increase in concentrations during this episode, in addition to the wind flow from metropolitan Denver in the direction of the Arsenal, include: 1) the morning rush hour from the Denver metropolitan area; 2) emissions from the nearby large sources such as Public Service Company - Cherokee Plant (see map designator #1 on Figure 5.7-1); 3) air traffic from Stapleton Airport; 4) a composite of the above and other metropolitan industrial activity, trapped under a very intense inversion and drifting toward RMA.

During the second period, the wind direction returned to a southwesterly component of approximately 225° after it changed to a northerly component. Again, the wind speeds were very light at less than 5 mph. Atmospheric conditions for this 9-hour period of extremely high concentrations were primarily stable to very stable (E to F stability class). These conditions were largely responsible for the poor air quality that was recorded during this period. Possible causes were the same as those stated for the first period. It is also possible that pollutants recorded earlier that migrated northward may have been "rechanneled" back into the Denver metropolitan area due to the changing winds, thus adding to an already accumulating "pool" of pollutants. This is not an uncommon situation because of the bi-modal upslope and downslope (drainage) pattern across the metropolitan area.

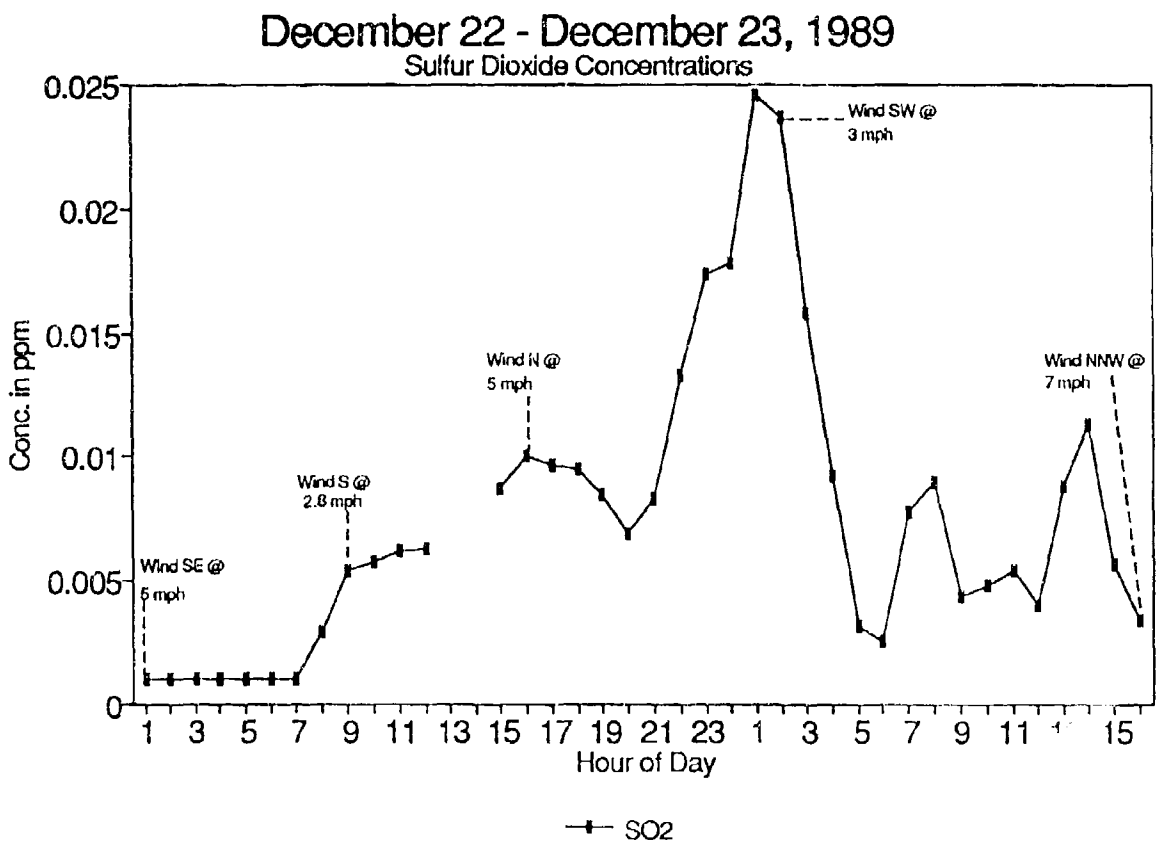
5.7.2 MAY 21, 1990

During the period from 0100 MST through 1200 MST on May 21, 1990, the RMA recorded the highest yearly 1-hour concentrations of sulfur dioxide (SO_2). At 0800 MST of this day, the hourly concentration of SO_2 was 0.05 ppm. This day was unique because the highest 1-hour concentration of SO_2 was recorded, but the other relevant air quality parameters of carbon monoxide including nitric oxide, nitrogen dioxide and nitrogen oxides were typical of the morning rush hour pattern, showing some elevations but no obvious peak concentrations.

The air quality and meteorological conditions that were present during this episode are presented in Table 5.7-5 and are also illustrated in Figures 5.7-5, 5.7-6 and 5.7-7. From these data, it is noted that the concentrations of all air quality parameters were near normal from 0100 MST to 0600 MST. There were slight increases in NO, NO_2 and NO_x, but again hardly a notable rise in the concentration. During these early hours of the morning, winds were primarily from the south to southwest; however, wind speeds were at first moderate (8 to 11 mph) and atmospheric stability was neutral. About 0400 MST, the surface inversion began to gain strength (stability categories E and F) and wind speeds



Prepared for : **U.S. Army Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado** Prepared by : **R.L. Stollar & Associates, Inc.** **Ebasco Services Inc.**	Figure 5.7-2 Graphical Depiction of Carbon Monoxide for December 22-23, 1989 **CMP AR FY90**



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U.S. Army Program Manager for
Rocky Mountain Arsenal
Commerce City, Colorado

Prepared by :

R.L. Stollar & Associates, Inc.
Ebasco Services Inc.

Figure 5.7-3
Graphical Depiction of
Sulfur Dioxide for
December 22-23, 1989

CMP AR FY90

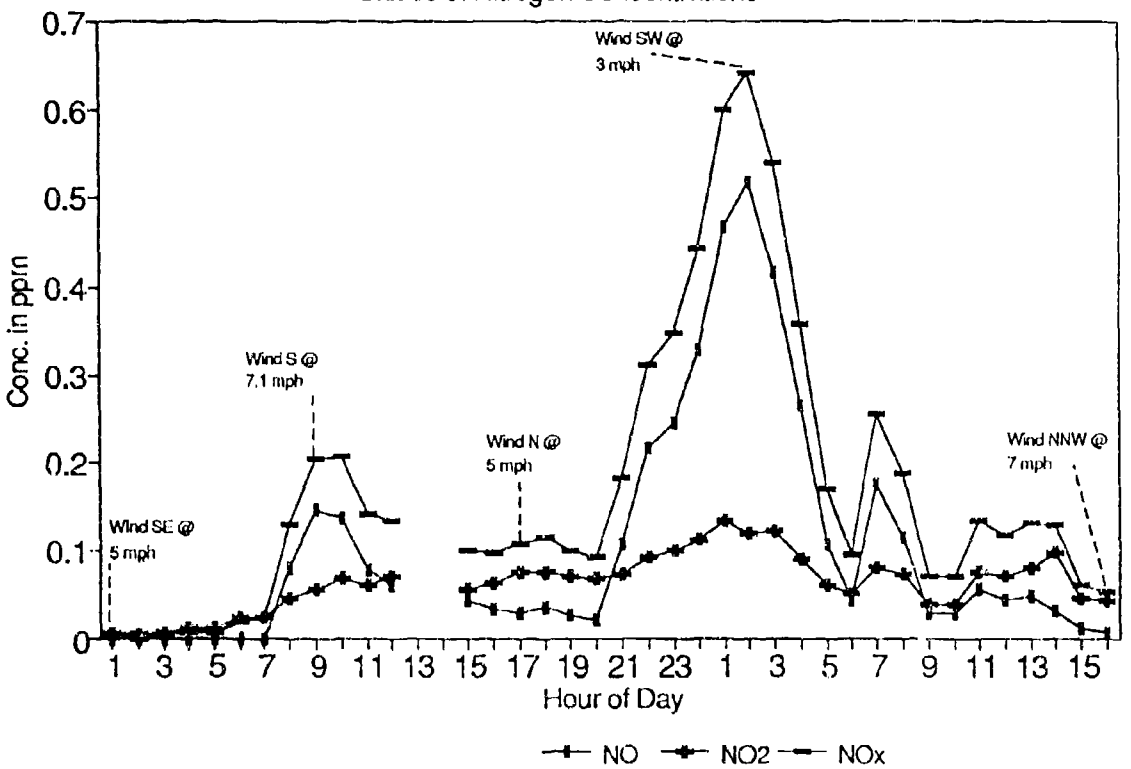

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Figure 5.7-4

Graphical Depiction of Nitrogen Oxides for December 22-23, 1989

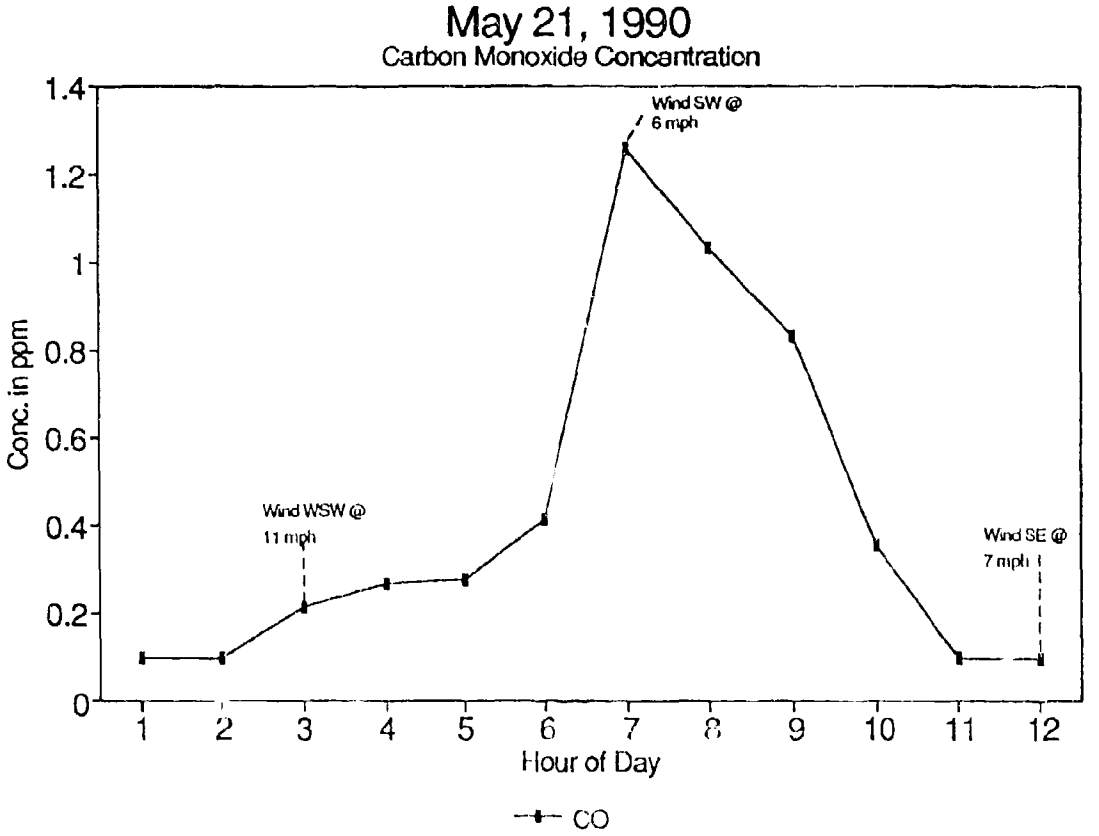
CMP AR FY90

Table 5.7-5 Relevant Air Quality and Meteorological Data for May 21, 1990

Calendar Month	Day	Hour MST	CO ppm	SO2 ppm	NO ppm	NO2 ppm	NO_x ppm	Wind Speed mph	Wind Direction deg	Temp deg F	Temp Diff* (10m-2m) deg F
5	21	100	0.100	0.001	0.001	0.009	0.011	7.8	198	50.6	3.0
5	21	200	0.100	0.001	0.001	0.010	0.011	6.9	200	49.4	4.3
5	21	300	0.213	0.001	0.001	0.013	0.014	10.9	211	48.3	3.1
5	21	400	0.269	0.003	0.001	0.026	0.028	4.8	241	47.4	3.5
5	21	500	0.276	0.004	0.001	0.029	0.031	3.9	222	47.5	4.0
5	21	600	0.413	0.003	0.013	0.026	0.040	5.3	219	48.1	3.2
5	21	700	1.259	0.008	0.051	0.040	0.092	6.0	215	50.7	-0.2
5	21	800	1.035	0.051	0.055	0.049	0.104	5.6	217	55.9	-0.4
5	21	900	0.830	0.028	0.033	0.041	0.074	5.4	194	60.9	-0.8
5	21	1000	0.357	0.004	0.004	0.015	0.020	6.2	169	66.3	-0.9
5	21	1100	0.100	0.001	0.001	0.005	0.007	6.5	158	70.0	-1.1
5	21	1200	0.100	0.001	0.001	0.003	0.005	7.0	141	72.2	-1.1

* It is noted that this is a very low level stability indicator near surface conditions. It may not always reflect upper atmospheric conditions.

AIR-TBL2.90



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Commerce City, Colorado

Prepared by :

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Ebasco Services Inc.

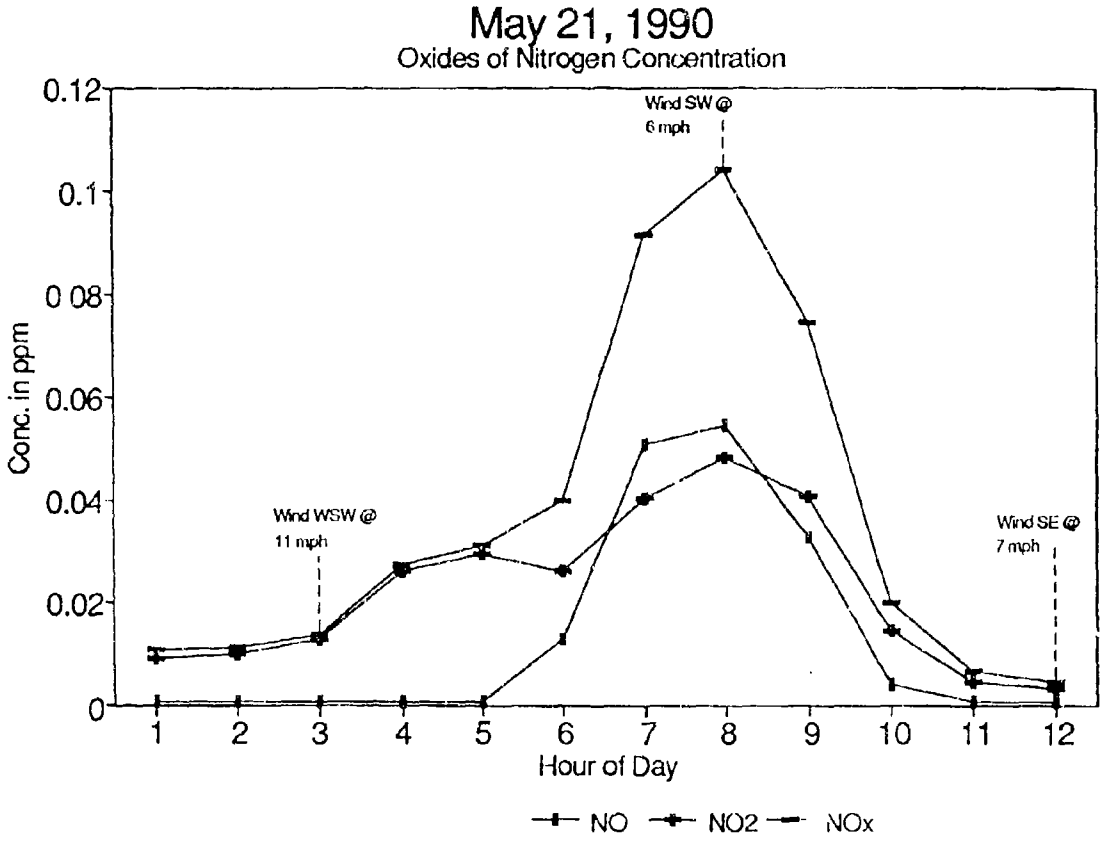
Figure 5.7-5

Graphical Depiction of

Carbon Monoxide for

May 21, 1990

CMP AR FY90



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Commerce City, Colorado

Prepared by :

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Ebasco Services Inc.

Figure 5.7-7
Graphical Depiction of
Nitrogen Oxides for
May 21, 1990

CMP AR FY90

decreased (4 to 5 mph). Pollutant levels increased during the next several hours reaching peak concentrations at 0800 MST. Shortly thereafter, the inversion began to dissipate and all criteria pollutant levels decreased to normal baseline values. very likely that the source of the higher SO_2 concentrations at 0800 MST was the Public Service Company - Cherokee Plant. The wind direction for the 3 previous hours, and for the hour of highest concentrations, was from the southwest, approximately 220°. This corresponds to the location where the plant would be directly upwind from the Arsenal.

It is of interest that the peak CO concentration at RMA, 1.26 ppm, was attained at 0700 MST while the peak SO_2 concentration occurred at 0800 MST. This might be explained by the vertical stability and wind profiles. Carbon monoxide is emitted from low level sources, resulting primarily from metropolitan Denver automobile traffic. At 0800 MST, the ground level stability (from "sigma theta" calculations) was already slightly unstable (category C) and CO levels began to decrease rapidly, returning to its lowest levels before noon when the atmosphere became highly unstable (category A). The winds also shifted, blowing toward the northeast away from the Arsenal. Sulfur dioxide, on the other hand, is emitted from higher level sources such as the tall stacks at the PSC Plant. It is unlikely that surface heating reached the height of the SO_2 plume until shortly after 0800 MST when concentrations began to decrease at the RMA site similar to the CO pattern.

The peak SO_2 concentration at RMA was considerably below the short-term Colorado Ambient Air Quality Standard (0.50 ppm for 3 hours). However, this example demonstrates how closely ambient concentrations from a pollutant emission source were determined by meteorological factors, and, in particular, wind flow and atmospheric stability. Since RMA is not a major source of criteria pollutants, all peak concentrations measured at the Arsenal were a reflection of the dispersion of emissions from upwind mobile and stationary sources (as shown in Figure 5.7-1). The CMP has documented numerous case studies ranging from typical morning surface inversions with modest impacts at RMA to intense winter surface inversion episodes and associated "brown cloud" conditions, where impacts on the Arsenal have been severe. These impacts, controlled by meteorological conditions, included not only gaseous pollutants but other components of industrial pollution such as TSP, PM-10 and metals discussed elsewhere in this report. Still another consequence is the effect on ambient visibility which is discussed in the next section. As will be shown, there were strong similarities and interrelationships between all of these effects.

6.0 PHOTO VISIBILITY STUDY

A Photographic Visibility Study was initiated during CMP FY90 to determine the relationship between the occurrence and intensity of observed dust at the Arsenal, and/or "brown cloud" conditions over the Denver metropolitan area, and the air quality recorded at RMA. This study incorporated the use of photographic records of visual air quality in correlation with particulate sampling and pollution gas data from the continuous monitoring site. These photographs were taken routinely (every 6th day) on EPA scheduled air quality sampling days. On these days samplers were run to measure total suspended particulates and PM-10, as well as for metals concentrations. Gaseous samplers measuring CO, O_3, SO_2, NO and NO_x were operated on a continuous basis.

In addition to the photographs which were taken on regularly scheduled sample days, photographs were taken during high wind dust events. These days, on occasion, produced short-term high dust conditions at localized areas such as Basin A. This portion of the visibility study was undertaken in conjunction with RMA to assist in determining the effectiveness of dust suppression treatment in the Basin A area, and also to help study the effects of high winds on the local visibility. When winds were in excess of 20 mph, or when actual visible dust clouds were created by winds in the Basin A vicinity, photographs were taken of this area.

The data from this study indicated direct relationships between visibility, wind direction, and gaseous air quality at RMA, especially when a heavy "brown cloud" was evident over portions of the metropolitan area. As might be expected, when the prevailing wind was blowing from the direction of the brown cloud toward the Arsenal, concentrations of gaseous pollutants were frequently measured at higher levels, and particulate concentrations at the perimeter air sampling sites were also elevated. The following sections describe several "episode days" which illustrate the relationships between RMA air quality and visibility as reflected by local wind-borne dust or the transport of Denver's industrial haze (or "brown cloud") conditions onto the Arsenal. It should be noted that the two types of dust events reflect two distinct meteorological scenarios. The brown cloud days are generally associated with inversion conditions, stable air and light to moderate winds. In contrast, on high wind dust event days, gaseous air quality frequently improved with higher wind speeds and increased mixing, but particulate concentrations increased due to the increased amount of wind-borne dust.

6.1 HIGH WIND DUST EVENTS

Several CMP studies have previously been reported relating the impacts of both wind gusts and RMA remedial activities to TSP, PM-10 and metals concentrations measured at various RMA locations (Stollar, 1988, 1989). It has been shown that during remediation activities Basin F and the Borrow Pit were principal areas contributing to visual dust and high TSP levels. After remediation, these areas were no longer significant sources of blowing dust. Basin A, similarly, has been a potential dust source of concern. However, the placement of dust suppressants over Basin A, and subsequent reduction of TSP concentrations over this area, has indicated the effectiveness of this mitigation program.

Nevertheless, there is a threshold of wind speeds and wind gusts which will lift dust particles off the open fields of the Arsenal (as well as surrounding rural areas); the previous Basin F remediation area and Basin A are especially susceptible to these conditions. The FY88 CMP Assessment Report (Stollar, 1989) suggested that wind gusts in excess of 25 mph were required to significantly increase TSP levels at the 12 RMA monitoring sites. A correlating study on metals concentrations in FY88 indicated that the highest metals levels were frequently associated with high wind speeds, but especially with strong gusts in excess of 25 mph. It is interesting that in FY89, the majority of high TSP and metals concentrations at the RMA were associated with brown cloud intrusions over the Arsenal, suggesting that multiple causal factors impact RMA air quality.

The FY90 visibility studies provide still another approach to evaluating air quality impacts at RMA. Photographs were taken in the vicinity of Basin A whenever wind speeds were in excess of 20 mph, or actual visible dust was observed. These photographic observations were taken from the Section 36 perimeter with a 35 mm lens. Actual recognition of the plumes on some prints may be difficult as a result of the wide angle lens; in several cases the dust and plume locations have been enhanced with markings superimposed on the photographs. Table 6.1-1 provides a summary of 11 visibility case studies conducted at Basin A when sustained winds were in excess of 20 mph. It is noted that gusts ranged from 34 to 49 mph, and can be considered a principal contributor to dust development. Winds ranged from west-southwest to northwest, which is generally the prevailing sector for strong winds at the Arsenal. It can be seen from the table that in several cases, resuspended particulate matter (dust) was not observed, confirming the variability and unpredictable nature of this phenomenon. In most cases, however, dust was observed and was frequently associated with the strongest winds and strongest gusts.

Table 6.1-1 Summary of High Dust Events During FY90

Date	Time	Wind Speed (mph)	Peak Gust (mph)	Direction	Observation
11-06-89	1215	20-23	34	NW	No dust observed
11-06-89	1230	20-23	34	NW	Some low dust
12-05-89	1430	20-26	37	NW	Widespread dust, entire area
01-08-90	1110	22-27	44	WSW	General low level dust, entire area
01-10-90	1340	22-24	44	NW	Light, low level dust cloud over center of Basin A
04-28-90	1025	19-27	41	WNW	Light, low level dust cloud over Basin A
05-15-90	1245	11-24	46	WNW	Widespread dust over Basin A; very high TSP levels (250 $\mu g/m^3$) just south of Basin A
05-18-90	1430	22-30	47	NW	Widespread dust over Basin A
06-21-90	1420	15-28	41	NE	Light, low level dust cloud over Basin A
07-23-90	1525	14-15	39	NW	Light, low level dust cloud over Basin A
09-10-90	1440	10-24	49	N	Low level dust over Basin A, but no distinct dust cloud

A typical strong dust event day was May 15, 1990 (see Figure 6.1-1). This was a very gusty day with a large amount of visible wind-borne dust. An observer at the Arsenal noted that small gravel was airborne along with the sand and dust. The maximum gust measured by the meteorological tower nearest to the site of the photograph was 46 mph. Winds were variable throughout much of the day, but were primarily from the southwest to northwest during the midday period. The photographs presented in Figure 6.1-1 show extremely reduced visibility in the Basin A vicinity. A group of large storage tanks about 200 yards from the photographer were nearly invisible behind airborne dust.

May 15, 1990, was not a routinely scheduled TSP sampling day. However, because of the forecast for high winds, high event monitoring was conducted on this date at a number of RMA monitoring sites. Table 6.1-2 shows the results of TSP monitoring for the period from 0800 MST on May 15 through 0800 MST on May 16, 1990.

Table 6.1-2 TSP Monitoring Results for May 15, 1990

Monitoring Site	Concentration (ug/m^3)
AQ1	55.6
AQ3	51.5
AQ4	43.9
AQ5	25.4
AQ6	55.1
AQ8	33.8
Mobile East	36.7
Mobile West	250.5

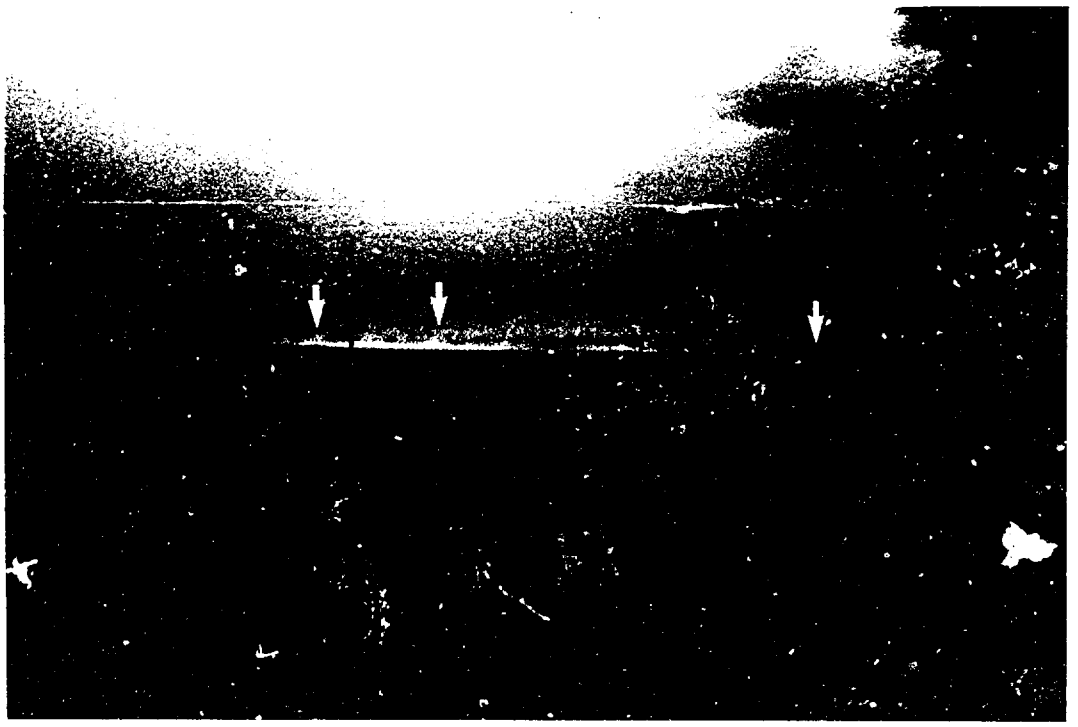
The greatest impact was experienced at Mobile West (Sampler No. M1B), which was located in the extreme northeast corner of Section 2, south of the Basin A Neck construction area. Other sites appeared to be above their normal TSP levels, in particular AQ6 which was also downwind from Basin A during much of the monitoring period. However, it is most interesting that except for Mobile West, impacts were not excessive; the event (shown in the photographs) was transitory (dust was lifted primarily during the peak gust period) and somewhat localized. The annual FY90 TSP results substantiate the effectiveness of the mitigation actions taken at Basin A and Basin F. On the other hand, the high levels at Mobile West confirm the difficulty in controlling dust under very high gust conditions during active construction activities.

Figure 6.1-1 Dust Event Case Study: May 15, 1990

PHOTO 1: Time of Day: 1250 MST Direction of Photo: West-northwest

Note: High, heavy clouds of wind-borne dust obscure most details in the photo. The storage tanks to the left are about 200 yards from the photographer.

PHOTO 2: Time of Day: 1250 MST Direction of Photo: Northwest



Note: There is a very visible white dust cloud in the center of the photograph, in Basin A. Windblown dust closer to the photographer reduces clear visibility in the foreground.

Air quality criteria pollutants were measured at moderate concentrations prior to the advent of high wind gusts at 0800 MST; the levels of CO, NO_x and SO_2 reflected the typical morning increase of the pollutants associated with the morning rush hour traffic activity south and west of the Arsenal. The levels of all criteria pollutants (except ozone) dropped dramatically when the wind speed increased. This is shown in Table 6.1-3 which provides a continuous record of criteria pollutants and meteorological data taken at the RMA monitoring sites. An abrupt change is noted at 0800 and 0900 MST coincident with the increased wind speed and wind gust conditio is. Pollutant patterns associated with this change are also illustrated in Figure 6.1-2. It is of interest that although criteria pollutant levels remained low, the poorest visibility conditions (reflected by the photographs in Figure 6.1-1) occurred near 1300 MST, when peak gusts reached 46 mph.

6.2 BROWN CLOUD EVENTS

Photographs were taken from the M4/AQ site location on each air sampling day. These photographs recorded visual conditions from the southwest to the northwest between RMA and the mountains located to the west of the Denver metropolitan area. On days of inclement weather which severely limited visibility, no photographs were taken. In addition to the photographic record, information such as weather conditions, ground conditions and general visibility were recorded on a data sheet. These data and the photographic evidence were then compared with gaseous data and particulate sampling results from that day. It should be stressed that the purpose of these evaluations was not to provide a definitive brown cloud study; the purpose rather, was to identify the impacts of metropolitan Denver industrial pollution on RMA air quality (and visibility) as measured under the CMP, and to distinguish between local RMA emissions and impacts, and external off-Arsenal emissions and impacts that comprise the RMA air quality baseline.

Once the photographs were returned from processing, further evaluation of conditions was made. A supplemental data sheet recorded the visibility of landmarks of known distances, and other observations made in evaluating the photographs. Both upper level visibility, which included Mount Evans, and lower level visibility were judged. During the summer months, visibility at both levels was usually good, but during the winter, visibility was frequently reduced, especially at the lower levels. The presence of a surface inversion and light winds usually created this lower level poor visibility scenario. These atmospheric conditions retarded the mixing between the colder lower level air and the warmer upper level air, and pollutants became trapped and concentrated in the lower air mass.

Table 6.1-3 May 15, 1990 Dust Event Data

Date	Hour	O3 ppb	CO ppm	SO2 ppb	NO ppb	NO2 ppb	NO_x ppb	Wind Speed mph	Wind Direction deg	Max. Wind Speed	Temp Diff* 10m-2m
5/15	100	22.69	0.27	1.00	1.00	13.09	14.35	9.63	298.70	16.79	1.42
5/15	200	23.23	0.10	1.00	1.00	6.65	7.91	9.04	36.25	15.30	0.75
5/15	300	20.71	0.10	1.00	1.00	6.10	7.19	6.04	208.20	12.06	2.25
5/15	400	17.09	0.10	1.00	1.00	12.83	13.60	5.56	185.90	9.36	6.36
5/15	500	6.73	0.38	1.00	1.00	22.74	23.77	8.08	188.40	11.23	4.03
5/15	600	5.58	0.77	6.61	20.34	31.13	52.36	9.10	213.60	19.57	1.24
5/15	700	17.26	0.88	7.20	23.74	35.40	60.02	8.41	212.10	17.23	-0.56
5/15	800	32.01	0.75	7.34	14.67	26.57	42.07	18.54	242.00	35.18	-1.00
5/15	900	51.58	0.10	1.00	1.00	4.16	4.25	19.83	266.20	29.22	-1.27
5/15	1000	51.53	0.10	2.80	1.00	5.72	7.23	17.00	266.60	25.20	-1.50
5/15	1100	55.23	0.10	1.00	1.00	2.05	1.00	12.85	323.70	25.74	-1.70
5/15	1200	57.04	0.10	1.00	1.00	2.52	3.04	13.52	18.60	21.49	-1.78
5/15	1300	58.64	0.10	1.00	1.00	3.07	3.59	13.22	333.90	46.09	-1.60
5/15	1400	52.00	0.10	1.00	1.00	3.98	4.92	26.81	296.80	44.45	-0.43
5/15	1500	56.85	0.10	1.00	1.00	2.36	2.92	12.11	317.80	22.90	-1.32
5/15	1600	55.84	0.10	1.00	1.00	2.15	4.14	20.19	317.90	30.20	-1.68
5/15	1700	53.20	0.10	1.00	1.00	2.70	3.62	14.61	328.10	32.83	-0.07
5/15	1800	48.45	0.10	1.00	1.00	4.14	4.68	12.55	330.20	19.86	0.46
5/15	1900	41.88	0.10	1.00	1.00	4.46	5.72	12.13	347.20	18.29	0.43
5/15	2000	42.96	0.10	1.00	1.00	3.03	3.66	8.12	56.66	17.09	0.90
5/15	2100	44.66	0.10	1.00	1.00	3.69	5.04	6.57	109.60	11.89	0.81
5/15	2200	48.04	0.10	1.00	1.00	1.00	3.53	3.55	156.40	15.27	0.70
5/15	2300	42.99	0.10	1.00	1.00	1.00	3.15	4.84	109.40	8.49	1.41
5/15	2400	40.05	0.10	1.00	1.00	1.00	3.68	7.87	339.20	17.82	0.88

* It is noted that this is a very low level stability indicator reflecting near surface conditions. It may not always reflect conditions at the top of the brown cloud, although it is frequently a precursor of true conditions.

AIR-TBL2.90

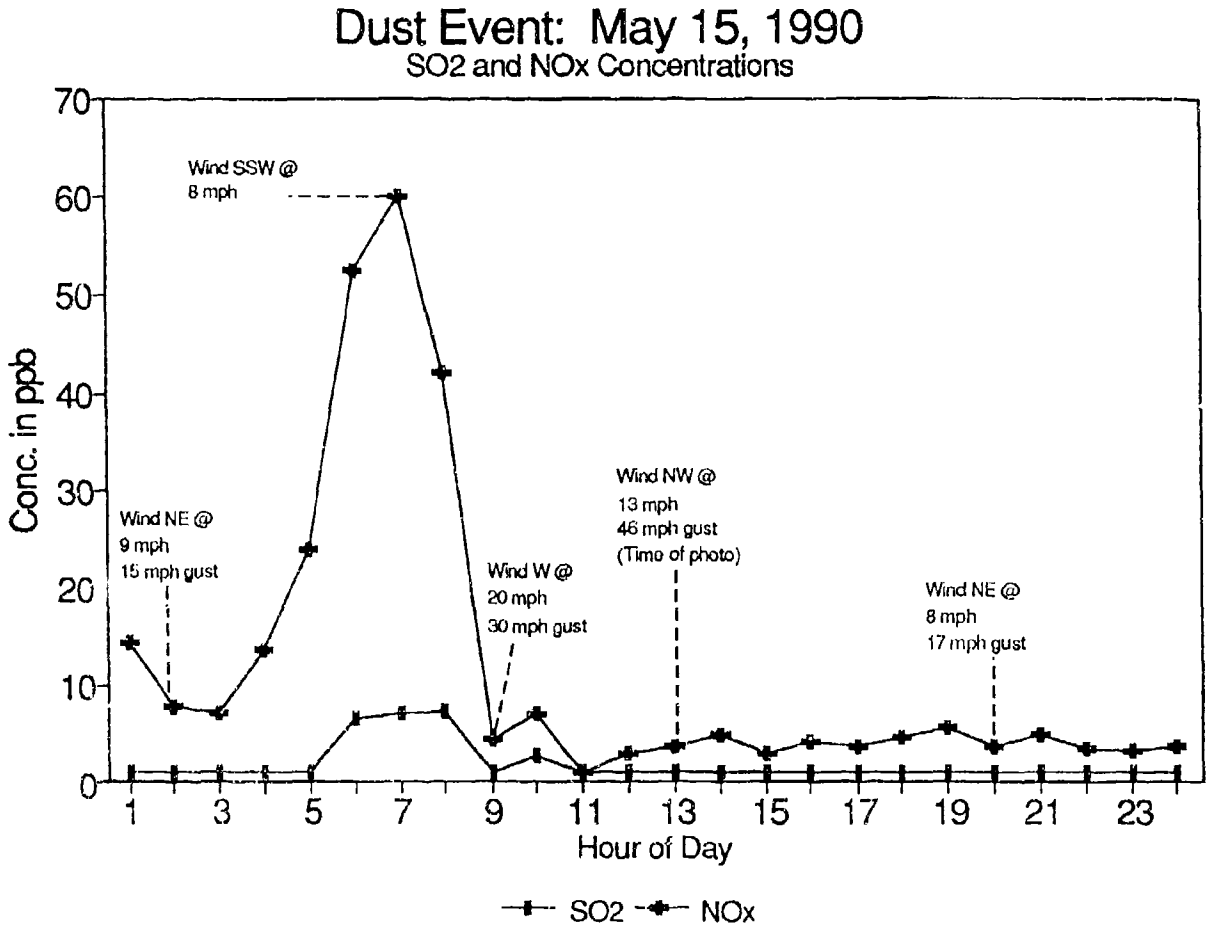


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Figure 6.1-2

Dust Event : May 15, 1990

(SO_2 and NOx)

CMP AR FY90

Upper level visibility was judged by the clarity of the high mountains visible from the RMA. Lower level visibility was judged by the clarity of closer landmarks such as the foothills and the buildings of downtown Denver, which were obscured when a brown cloud was suppressed by a surface inversion. Visibility was classified as excellent, good, fair or poor depending upon the clear visibility of certain landmarks.

The judging criteria were as follows:

> Excellent Visibility - Mount Evans (52 miles) was clear and sharp, as were all foreground landmarks.
>
> Good Visibility - The foothills and Hogback (21 miles) were clear and sharp, even at the very bottom. Mountains may or may not be clearly visible.
>
> Fair Visibility - The foothills and Hogback were indistinct, but the Denver skyline (10.5 miles) was clearly visible.
>
> Poor Visibility - The Denver skyline was not distinct, or not visible.

Thirty-eight percent of the cases were in the poor visibility category. It should be noted that the scheduled photographs were taken during the morning periods when rush hour traffic was heaviest, and the gaseous pollutants measured at the RMA continuous monitoring site were generally at their highest levels; when inversion conditions persisted, visibility was frequently at its poorest levels for the entire day as well. The photographic record kept during FY90 has proven useful in evaluating above average gaseous pollution days at RMA.

When the brown cloud was unmistakably evident, and the wind blew from metropolitan Denver across RMA, gaseous pollutant concentrations were consistently higher than normal. As might be expected, on days when a surface inversion existed, but the brown cloud drifted away from the Arsenal, normal or better than average air quality readings were recorded at the Arsenal. It is interesting that on several days when the brown cloud was transported to the north or northwest of Denver under a southerly wind flow, and winds then shifted to a steady westerly or northwesterly component, air quality criteria pollutant levels abruptly increased at the Arsenal monitoring site. Data strongly suggest that the air quality of the RMA is directly influenced by the presence and position of the

brown cloud. Several examples illustrating brown cloud impacts under various meteorological scenarios are provided below.

October 25, 1989

October 25, 1989, was a day with particularly poor visual air quality. Though the upper level visibility was good and distant mountains could be seen clearly from RMA, the lower level visibility was poor. The foothills, particularly the lower portion, were obscured by an obvious brown haze. The brown cloud, as evidenced by the photographs in Figure 6.2-1, was most dense toward the north, but stretched all along the front range; Photo 1 is directed to the southwest and Photo 2 is directed to the northwest from the Arsenal monitoring site.

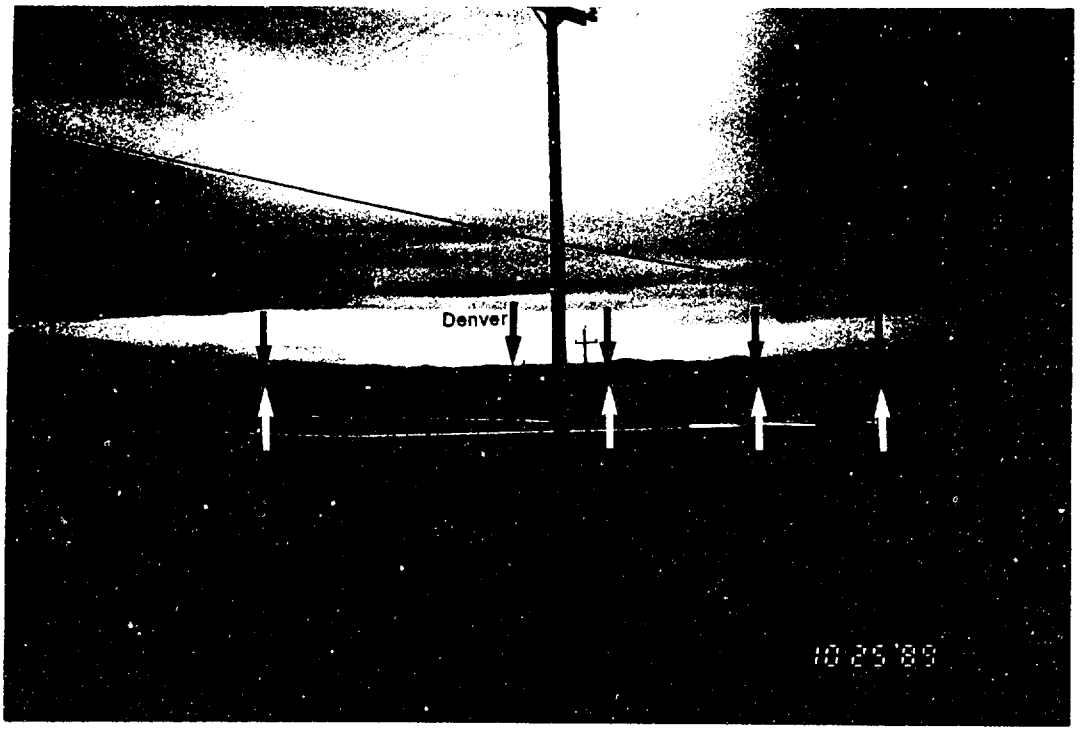
The wind varied from south-southwest in the early morning hours to westerly around midday, then northwest from early afternoon to late evening when it turned again to a southerly wind. The winds, therefore, pushed the brown cloud toward the north and northeast during the early hours of the day, then to the east (toward the Arsenal) at midday. Table 6.2-1 provides a continuous record of criteria pollutants and meteorological data collected at RMA on October 25, 1989. The result of the wind shifts was that the brown cloud remained upwind of the RMA continuous air monitoring site until late morning when the westerly component of the wind resulted in increased criteria pollutant levels recorded at the Arsenal monitoring site. Figure 6.2-2 illustrates the migration of the brown cloud with wind shifts during the day.

The recorded values for all gaseous parameters except ozone were noticeably higher than the October monthly averages and the yearly averages. Since ozone production is a photochemical process and the day was uniformly overcast, ozone production would be expected to be lower than normal. Figures 6.2-3 and 6.2-4 present the daily summary of gaseous (SO_2, NO_x, and CO) data, as well as pertinent meteorological data for October 25, 1989. These figures illustrate trends in concentrations of representative gaseous pollutants throughout the day. In general, there appears to be a slight lag between wind direction shifts and gaseous pollutant concentrations.

As a regular air sampling day, October 25, 1989, also registered considerably higher than normal TSP and PM-10 particulate concentrations at all sites, as well as elevated metals levels at some sampling sites. The highest particulate concentrations collected during this day were at the perimeter air sampling stations at the west (AQ1), and northwest (AQ2) boundaries of RMA. AQ1 measured 133 $\mu g/m^3$ and AQ2 measured 161 $\mu g/m^3$, exceeding the Colorado 24-hour AAQS. The October 25 data

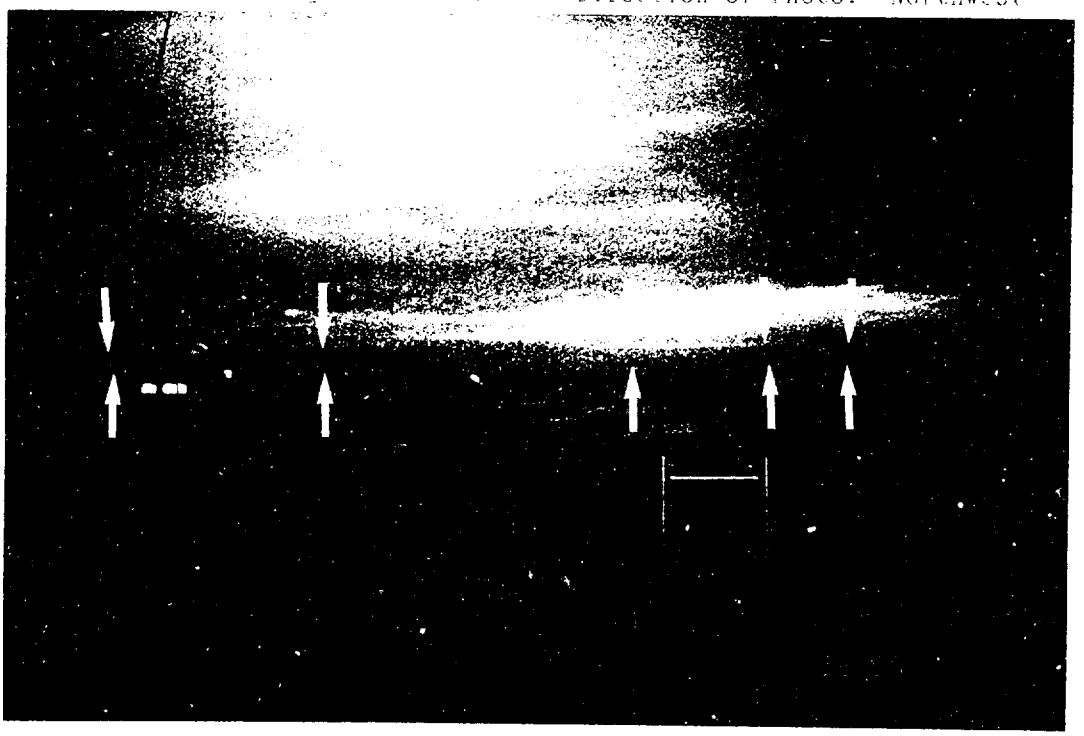
Figure 6.2-1 Brown Cloud Case Study: October 25, 1989

PHOTO 1: Time of Day: 0745 MST Direction of Photo: Southwest



Note: Downtown Denver is centered in the photo. The Hungarian Flour Mill is to the right of the building, behind the more distant powerpole. Both landmarks are indistinct in the brown cloud. The lower foothills are also obscured.

PHOTO 2: Time of Day: 0749 MST Direction of Photo: Northwest



Note: Behind the storage tanks, normally visible foothills, are completely obscured. The brown cloud is clearly visible as a thick brown band to the north.

Table 6.2-1 October 25, 1989 Brown Cloud Event Data

Date	Hour	O3 ppb	CO ppm	SO2 ppb	NO ppb	NO2 ppb	NO_x ppb	Wind Speed mph	Wind Direction* deg	Max. Wind Speed
10/25	100	5.54	0.86	1.00	1.00	31.75	34.41	9.03	209.40	9.88
10/25	200	8.48	0.71	1.00	1.00	24.55	23.46	9.27	204.30	9.95
10/25	300	11.55	0.61	1.00	1.00	16.86	16.98	10.74	213.70	12.93
10/25	400	5.93	0.67	2.48	6.60	26.61	34.21	9.01	234.60	12.07
10/25	500	1.00	0.63	3.38	7.06	31.09	39.15	6.24	221.30	8.59
10/25	600	5.67	0.65	2.25	7.42	27.26	35.61	5.55	254.60	8.70
10/25	700	8.23	0.71	6.23	15.19	27.08	43.26	5.33	317.90	5.96
10/25	800	11.07	0.97	6.68	28.01	26.56	55.62	3.29	279.90	5.32
10/25	900	3.07	2.71	13.96	133.80	48.62	183.60	5.60	243.10	9.98
10/25	1000	2.91	3.30	12.28	130.00	54.69	185.90	3.84	269.90	5.35
10/25	1100	4.92	2.57	10.87	88.20	58.88	148.20	1.70	291.50	4.66
10/25	1200	16.30	1.44	3.62	34.91	35.51	71.40	10.52	184.50	18.49
10/25	1300	18.23	0.73	1.00	3.95	16.86	21.80	10.71	206.30	14.03
10/25	1400	8.43	1.36	4.55	24.45	46.37	71.80	6.67	340.20	9.28
10/25	1500	8.78	1.41	7.59	29.11	48.76	78.90	8.76	16.10	11.72
10/25	1600	13.69	1.19	4.17	23.65	40.82	65.51	8.07	15.55	10.65
10/25	1700	11.18	0.89	2.38	4.84	33.98	39.80	6.14	20.44	11.01
10/25	1800	1.00	1.15	1.00	11.57	48.09	60.67	6.18	321.90	10.79
10/25	1900	1.00	1.14	2.12	22.11	48.42	71.50	5.86	326.10	6.90
10/25	2000	1.00	1.17	2.44	28.33	53.44	82.90	5.50	322.30	5.33
10/25	2100	1.00	1.24	3.25	16.24	51.81	68.99	3.86	228.70	7.83
10/25	2200	1.00	1.09	1.00	15.67	41.78	58.45	10.41	154.10	15.44
10/25	2300	13.77	0.71	1.00	1.00	19.33	21.24	10.81	172.40	15.28
10/25	2400	16.38	0.58	1.00	1.00	13.13	14.42	12.68	163.30	14.60

NOTE: Temperature differences (10m-2m) instrumentation was not yet installed.

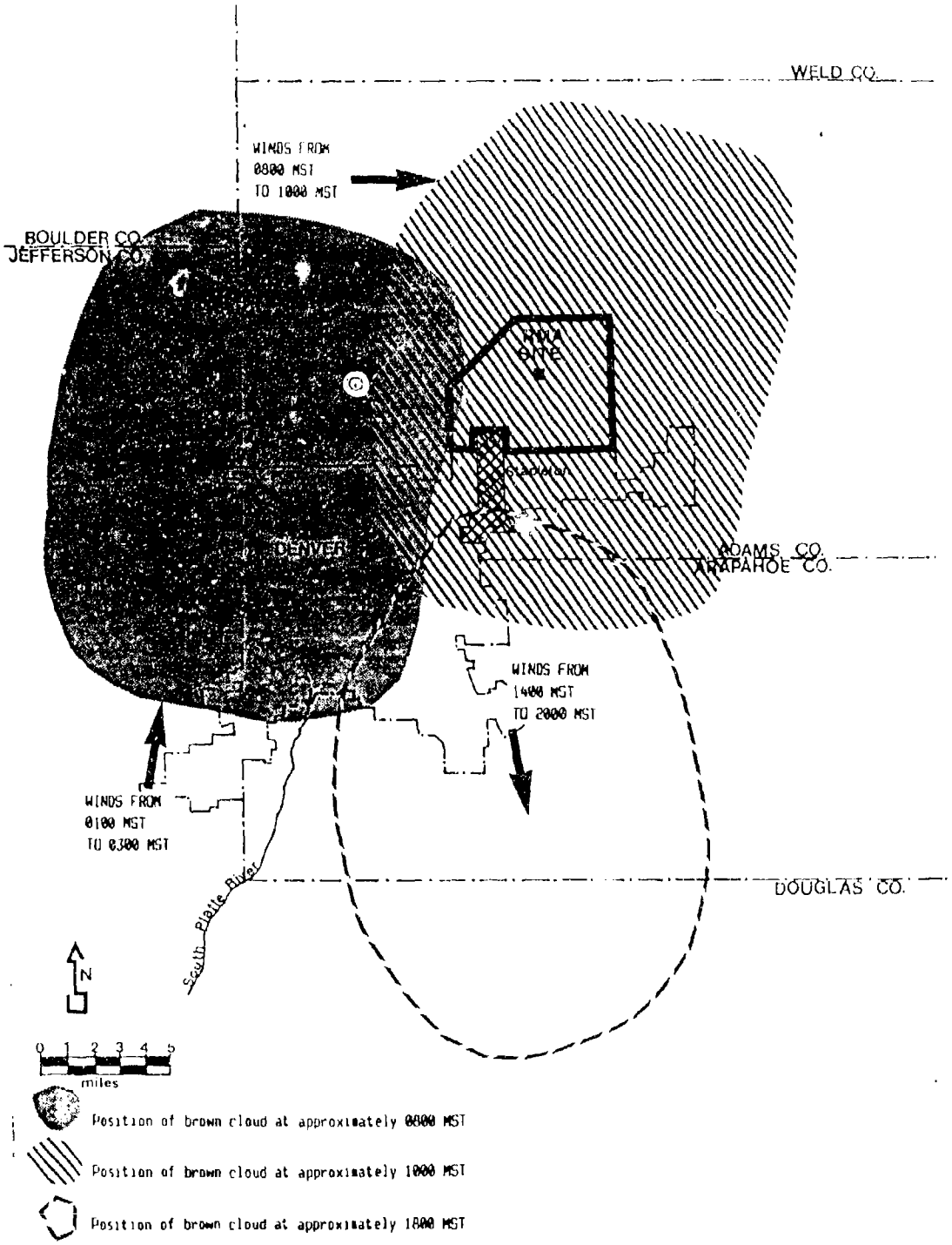


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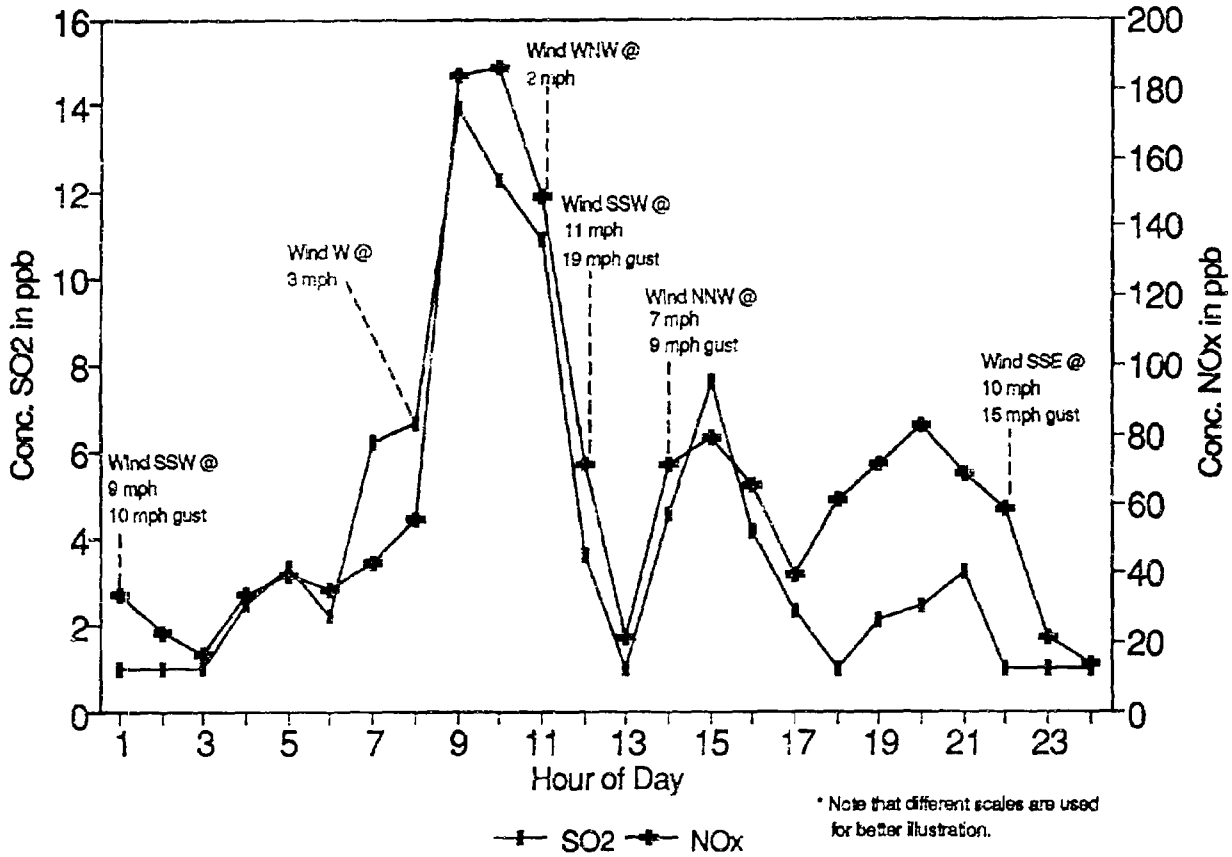
Figure 6.2-2

Brown Cloud Migration:
October 25, 1989

Brown Cloud Event: October 25, 1989

SO2 and NOx Concentrations



* Note that different scales are used for better illustration.

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Figure 6.2-3
Brown Cloud Event :
October 25, 1989
(SO_2 and NOx)

CMP AR FY90

Brown Cloud Event: October 25, 1989

CO Concentration

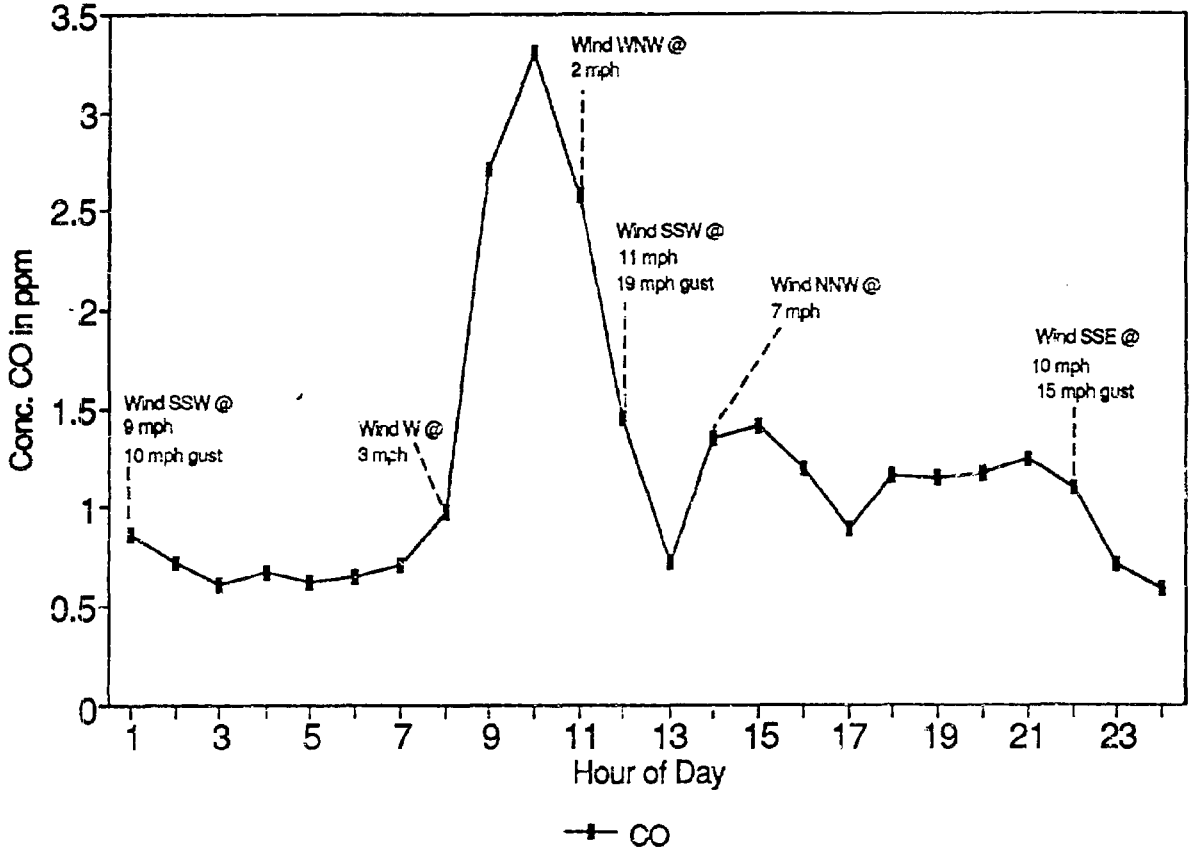

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Figure 6.2-4
Brown Cloud Event :
October 25, 1989
(CO)

CMP AR FY90

indicate the direct impact of both particulate pollutants and criteria gaseous pollutants from outside sources upon the air quality of RMA.

January 5, 1990

The photographs for January 5, 1990, illustrate a typical winter day with an intense morning inversion, which dissipated during the day and then reestablished itself during the evening hours; Figure 6.2-5 illustrates this case. An interesting pattern was established between the wind direction and the air quality throughout the day, as indicated by pollutant concentrations recorded at the RMA continuous air quality monitoring site. When the wind blew from the direction of the brown cloud, the gaseous air quality degraded. When the wind blew from the opposite direction, the air quality was much improved. Table 6.2-2 presents the daily summary of gaseous pollutant and wind direction data. Figures 6.2-6 and 6.2-7 also illustrate the concentration levels of representative pollutants for the day.

In the early hours of the day while the inversion was strong, the winds were light and from the south-southwest to west. Concentrations of nitrogen oxides and carbon monoxide were noticeably higher than normal at the RMA monitoring site during these hours. Coincident with a wind shift to the east-northeast, these values dropped to more normal levels. When the winds again shifted back to the west and southwest at the end of rush hour, concentrations also climbed again. At noon another wind shift from the north-northeast was accompanied by a drop in pollutant concentrations for the remainder of the day; wind speeds also increased significantly, signalling a break in the inversion and increased mixing. Later in the evening, the winds shifted from easterly to southerly; also, the inversion was reestablished. These new conditions coincided with the highest concentrations of the day.

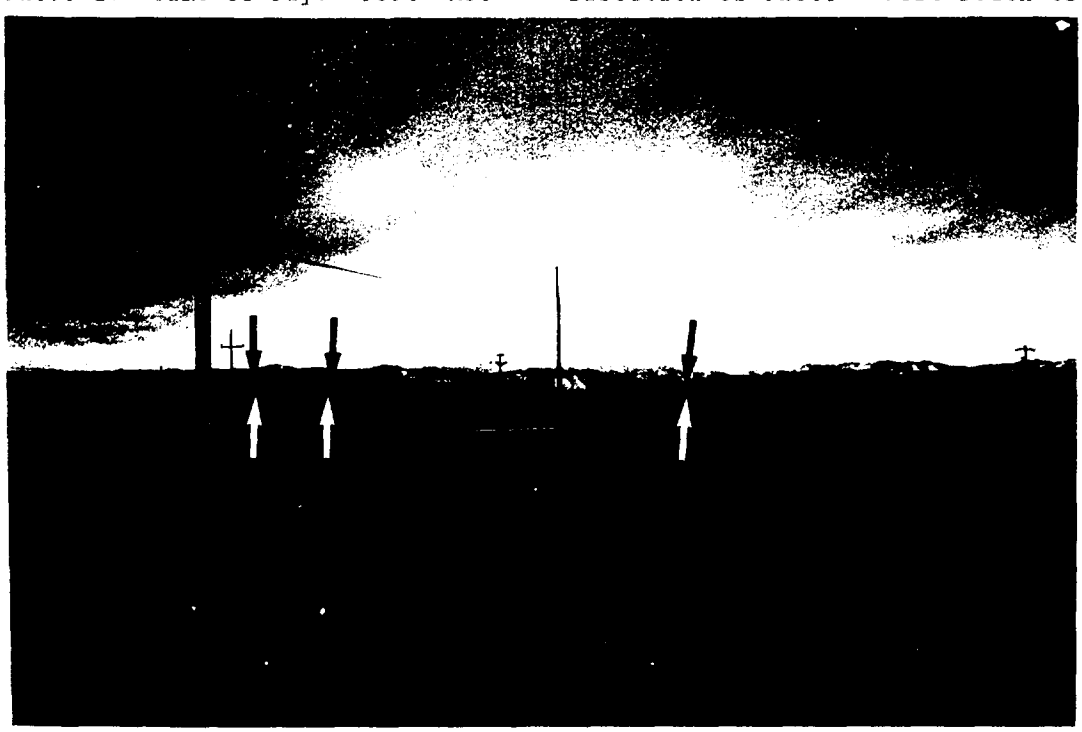
In addition to the elevated gaseous criteria pollutant concentrations, considerably higher than normal TSP and PM-10 concentrations were measured at RMA perimeter sites closest to Denver. AQ1 and AQ2 on the western and northwestern boundaries both measured 72 ug/m^3, while AQ5 on the southern boundary measured 124 ug/m^3. It is particularly interesting that in the previous example (October 25, 1989), the western boundary stations measured the highest TSP concentrations with the brown cloud drifting back onto the Arsenal from the west and northwest. In this example, the advection was strictly from the south, and the southern boundary stations measured significantly higher concentrations. This was also true for PM-10 levels on this date. Again, this case illustrates the direct relationships between Arsenal air quality conditions, metropolitan Denver influences, and pertinent meteorological factors such as wind speed, wind direction, inversion conditions and stability.

Figure 6.2-5 Brown Cloud Case Study: January, 5, 1990

PHOTO 1: Time of Day: 0806 MST Direction of Photo: South-southwest

Note: Downtown Denver is centered in photo behind the powerpole and is indistinct in the brown cloud. The lower foothills are also obscured behind the lowlying gray-brown smog.

PHOTO 2: Time of Day: 0804 MST Direction of Photo: West-southwest



Note: The brown cloud obscures the view of the lower half of the foothills.

Table 6.2-2 January 5, 1990 Brown Cloud Event Data

Date	Hour	O3 ppb	CO ppm	SO2 ppb	NO ppb	NO2 ppb	NO_x ppb	Wind Speed mph	Wind Direction deg	Max. Wind Speed	Temp Diff* 10m-2m
1/5	100	1.00	1.89	1.00	23.88	42.20	67.13	5.46	219.30	8.36	4.18
1/5	200	1.00	1.78	1.00	21.22	41.93	64.15	4.45	197.80	9.10	3.02
1/5	300	2.58	1.56	2.91	11.06	39.29	51.27	3.84	253.60	6.40	3.62
1/5	400	8.29	1.33	2.14	1.00	33.66	35.53	3.34	284.60	6.09	1.99
1/5	500	3.97	1.35	2.70	7.73	37.91	46.61	3.48	170.00	6.42	3.89
1/5	600	12.72	1.23	1.00	1.00	30.06	31.83	1.47	74.60	4.02	3.05
1/5	700	15.42	1.21	1.00	1.00	27.14	29.83	1.43	105.70	4.39	3.42
1/5	800	15.57	1.24	1.00	3.90	25.84	30.71	1.77	322.50	6.00	3.65
1/5	900	12.66	1.63	3.90	32.83	38.70	72.60	3.02	252.50	6.67	2.73
1/5	1000	19.88	1.78	1.00	26.05	32.26	59.31	3.90	274.60	9.29	-0.18
1/5	1100	33.28	1.18	1.00	9.36	14.09	24.42	10.72	15.94	14.18	-0.35
1/5	1200	38.41	0.98	1.00	6.60	5.54	13.14	12.59	38.06	16.45	-0.46
1/5	1300	39.85	0.94	1.00	4.62	3.42	9.00	11.33	10.04	17.43	-0.63
1/5	1400	39.55	0.95	1.00	2.99	3.98	7.91	9.32	18.45	17.02	-0.45
1/5	1500	38.69	0.94	1.00	2.45	3.81	7.30	11.42	28.41	14.39	-0.24
1/5	1600	37.69	0.92	1.00	2.85	3.31	7.20	9.27	44.24	13.95	0.11
1/5	1700	34.08	0.94	1.00	2.68	4.06	7.73	4.34	79.70	6.06	1.22
1/5	1800	31.97	0.95	1.00	3.50	5.40	9.86	4.79	126.50	7.20	4.57
1/5	1900	12.57	1.18	1.00	6.77	22.22	29.95	9.43	144.20	12.53	7.05
1/5	2000	1.00	1.33	1.00	9.69	31.32	42.00	9.67	160.70	12.82	5.11
1/5	2100	2.40	2.54	1.00	85.30	37.83	124.30	7.86	176.20	11.62	2.79
1/5	2200	4.56	1.76	1.00	24.71	33.81	59.47	9.80	173.40	12.10	2.29
1/5	2300	4.01	1.45	1.00	2.58	34.39	37.85	10.35	173.30	11.05	2.21
1/5	2400	2.22	1.41	1.00	3.28	35.70	40.04	8.22	176.30	8.86	2.56

* It is noted that this is a very low level stability indicator reflecting near surface conditions. It may not always reflect conditions at the top of the brown cloud, although it is frequently a precursor of true conditions.

AIR-T8L2.90

Brown Cloud Event: January 5, 1990

SO2 and NOx Concentrations

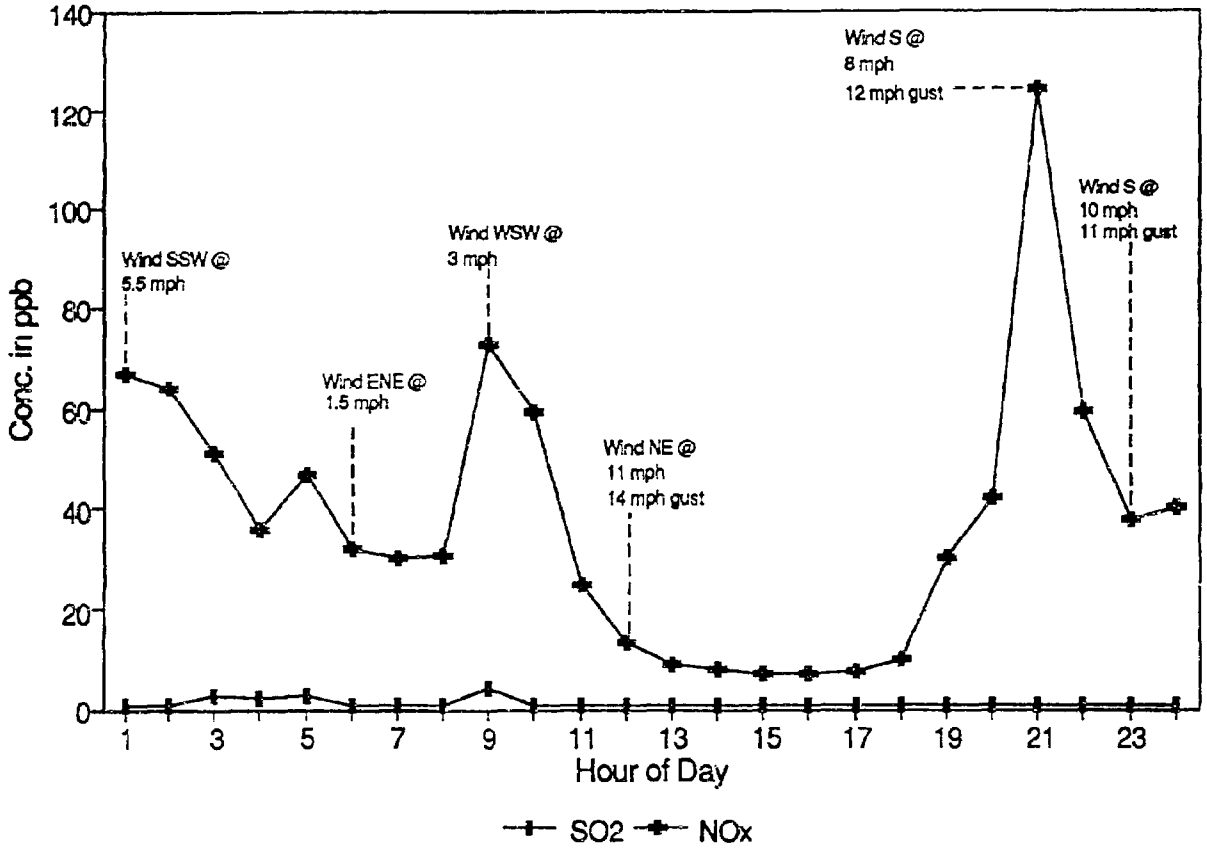


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Figure 6.2-6

Brown Cloud Event :

January 5, 1990

(SO_2 and NOx)

CMP AR FY90

Brown Cloud Event: January 5, 1990

CO Concentration

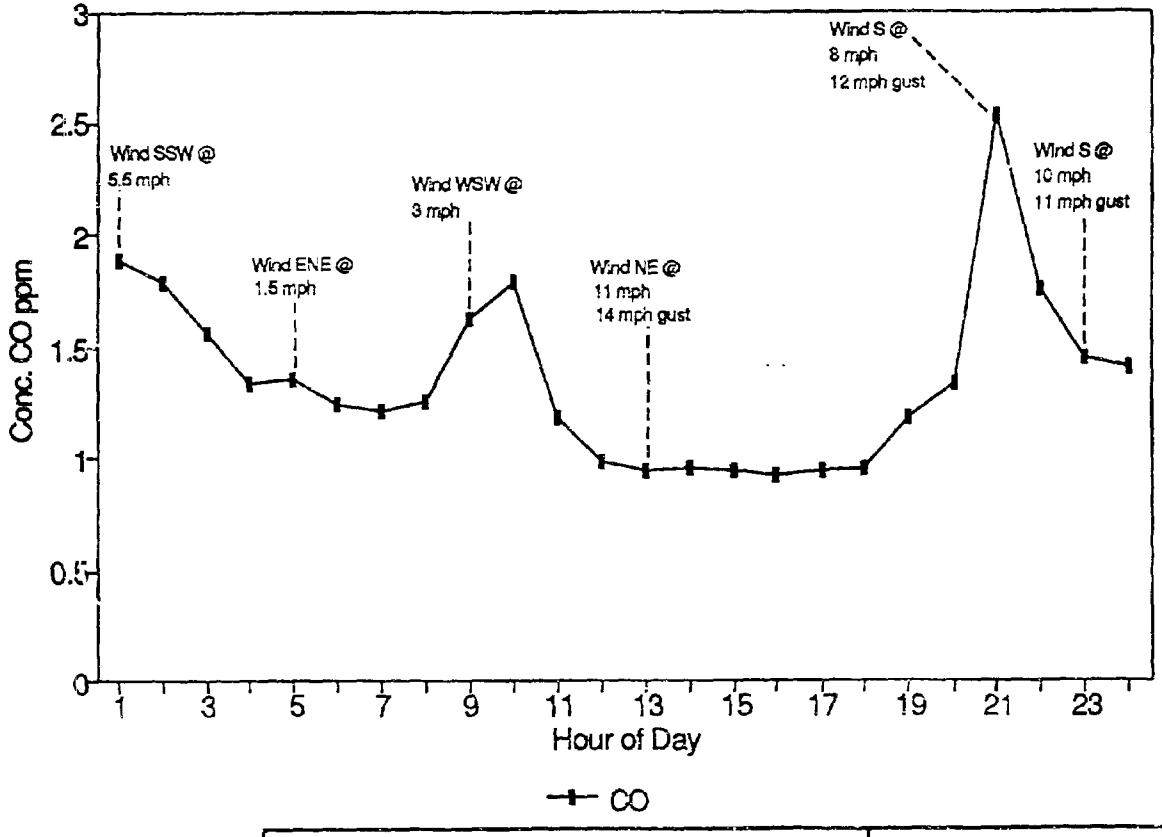

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Figure 6.2-7

Brown Cloud Event :
January 5, 1990
(CO)

CMP AR FY90

September 14, 1990

The morning of September 14, 1990, was a period of very poor air quality throughout the Denver metropolitan area, as well as statewide. Analyses of particulate samples in Denver and at RMA showed the highest concentrations of particulates for the year at most sites. PM-10 concentrations were also near their highest levels. Photographs taken on this day show a general, heavy haze of a gray-brown tint, and very poor visibility (see Figure 6.2-8). The foothills cannot be seen through the haze, and the downtown Denver buildings are barely discernable. All areas west of the RMA shown in these photographs exhibit heavy visible pollution within the haze.

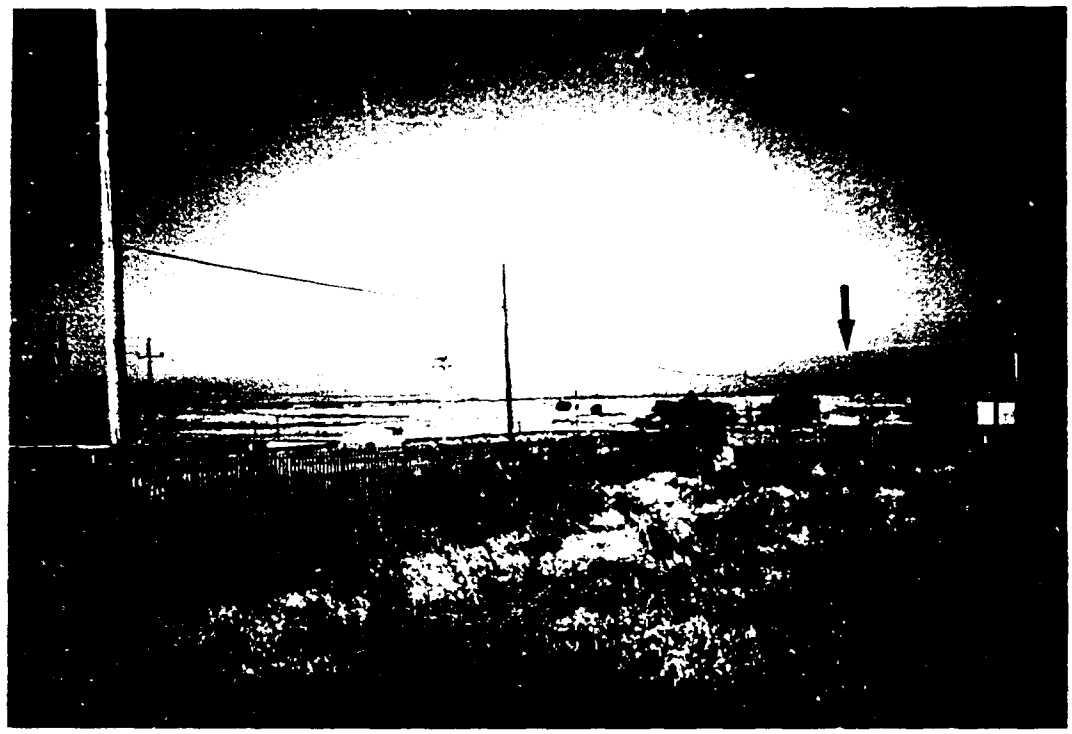
September 14, 1990, has been documented previously in Section 4.2. This was a "limited mixing" day with an upper inversion capping the release of emissions from the boundary layer. Air quality was not only poor in the metropolitan Denver area, but throughout eastern Colorado. Meteorological data for the day indicate a dual level inversion; one at the surface, and the other at about 8,000 to 9,000 ft (3,000 to 4,000 ft above the surface). The upper limit of the lower level inversion can be seen in Photo No. 2 of Figure 6.2-8, which was taken facing to the north at about 0725 MST. This lower level inversion likely contributed to the poor air quality at the RMA during the day, while the higher level inversion helped prolong the lower inversion.

Criteria pollutants monitored by the RMA continuous air quality monitoring site showed high concentrations coincident with rush hour, and a wind shift from southeast to southwest which brought the flow from Denver directly over the Arsenal. Table 6.2-3 summarizes gaseous pollutant data and pertinent meteorological data for September 14, 1990. Figures 6.2-9 and 6.2-10 illustrate pollutant patterns for CO, SO_2 and NO_x on this sampling day. (Unfortunately the NO_x monitor was out of service after 1100 MST.) Above normal pollutant levels were sustained until midmorning when several meteorological factors began to change and improve the air stagnation pattern. As surface heating continued, the low level inversion was broken, wind speeds increased and winds also shifted to a northerly component. Also, the upper level inversion weakened, as reflected by the late afternoon sounding for Denver. During the early evening, the surface inversion began to reestablish itself and pollution levels began to climb again, particularly CO, as noted in Figure 6.2-10.

Of interest in this example is that while gaseous data did not indicate excessively high pollution levels, (although they were above typical morning rush hour values), very high concentrations of TSP and PM-10 were especially significant on this day. Concentrations on this particular day were probably

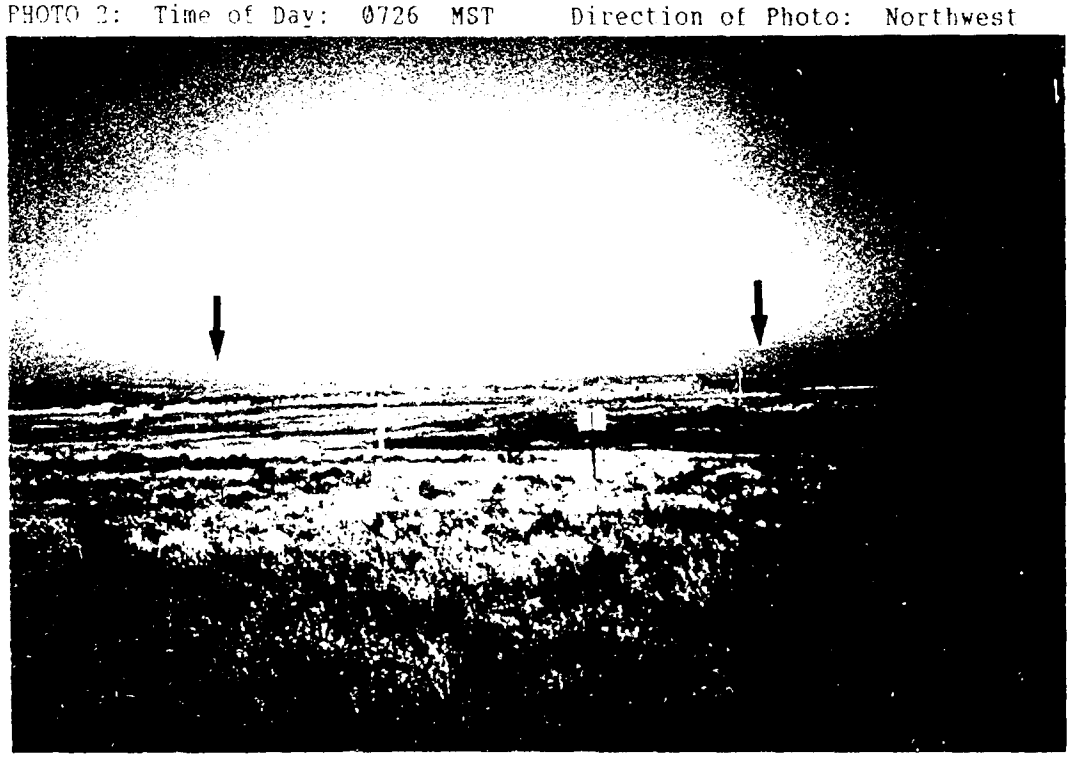
Figure 6.2 8 Brown Cloud Case Study: September 14, 1990

PHOTO 1: Time of Day: 0725 MST Direction of Photo: West southwest



Note: Downtown Denver at the left edge of the photo, behind the powerpole, is barely visible. The Hungarian Flour Mill to the left of center, is indistinct in the haze. The foothills are virtually invisible, as are the mountains.

PHOTO 2: Time of Day: 0726 MST Direction of Photo: Northwest



Note: The brown cloud obscures the foothills and appears as a broad brown band above the northern horizon.

Table 6.2-3 September 14, 1990 Brown Cloud Event Data

Date	Hour	O3 ppb	CO ppm	SO2 ppb	NO ppb	NO2 ppb	NO_x ppb	Wind Speed mph	Wind Direction deg	Max. Temp Speed	Temp. Diff. 10m-2m
9/14	100	25.25	0.10	1.00	2.62	8.08	11.50	4.36	347.10	5.50	2.01
9/14	200	24.14	0.10	1.00	2.68	7.50	11.06	4.21	74.00	7.62	1.96
9/14	300	23.03	0.10	1.00	2.80	6.78	10.46	4.55	138.80	9.37	3.37
9/14	400	10.38	0.10	1.00	2.80	15.07	18.72	6.83	157.80	10.13	4.70
9/14	500	8.33	0.10	1.00	2.58	13.57	16.96	8.75	143.50	12.30	4.60
9/14	600	9.43	0.20	1.00	2.65	11.86	15.35	8.65	148.40	13.02	2.55
9/14	700	7.03	0.51	1.00	13.35	18.07	32.21	5.79	161.90	10.72	0.26
9/14	800	10.85	0.68	9.39	30.50	28.45	59.64	2.94	219.60	7.04	-0.66
9/14	900	20.59	0.38	9.22	18.99	21.99	41.70	2.45	133.80	9.96	-1.03
9/14	1000	27.59	0.46	5.63	14.92	22.41	38.06	5.41	324.70	10.54	-1.10
9/14	1100	37.24	0.32	2.76	N/A	N/A	N/A	7.85	320.10	12.43	-1.40
9/14	1200	49.67	0.23	1.00	N/A	N/A	N/A	5.33	307.50	14.69	-1.46
9/14	1300	63.48	0.23	1.00	N/A	N/A	N/A	5.01	283.00	11.86	-1.41
9/14	1400	71.30	0.23	1.00	N/A	N/A	N/A	4.93	341.20	11.27	-1.39
9/14	1500	78.10	0.25	1.00	N/A	N/A	N/A	4.46	329.60	10.74	-1.27
9/14	1600	73.60	0.28	1.00	N/A	N/A	N/A	7.42	317.60	11.60	-1.33
9/14	1700	INVAL	0.30	1.00	N/A	N/A	N/A	8.29	325.20	11.27	-0.96
9/14	1800	68.24	0.33	1.00	N/A	N/A	N/A	6.75	318.40	10.09	0.54
9/14	1900	67.42	0.51	1.00	N/A	N/A	N/A	3.05	304.10	4.83	1.86
9/1	2000	64.56	0.51	1.00	N/A	N/A	N/A	4.21	147.70	10.79	5.77
9/14	2100	34.07	0.99	3.13	N/A	N/A	N/A	5.56	136.80	10.84	8.84
9/14	2200	21.33	0.85	2.41	N/A	N/A	N/A	5.81	161.40	11.16	5.77
9/14	2300	11.08	1.09	3.05	N/A	N/A	N/A	6.66	197.10	10.64	4.04
9/14	2400	13.04	0.88	1.00	N/A	N/A	N/A	6.63	190.70	10.10	2.91

* It is noted that this is a very low level stability indicator reflecting near surface conditions. It may not always reflect conditions at the top of the brown cloud, although it is frequently a precursor of true conditions.

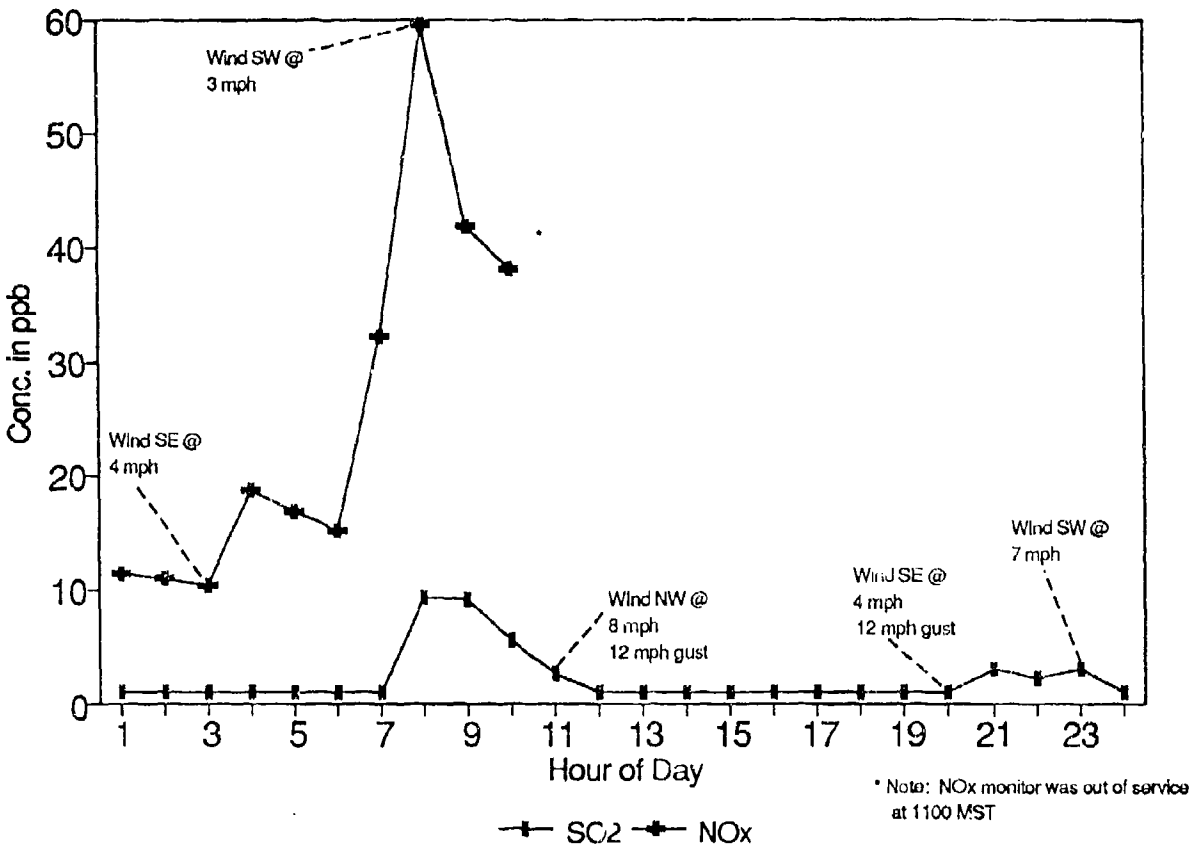
Explanation of abbreviations used:

INVAL: Denotes invalid data for this time period.
N/A: Denotes unavailable data for this time period.

AIR-TBL2.90

Brown Cloud Event: September 14, 1990

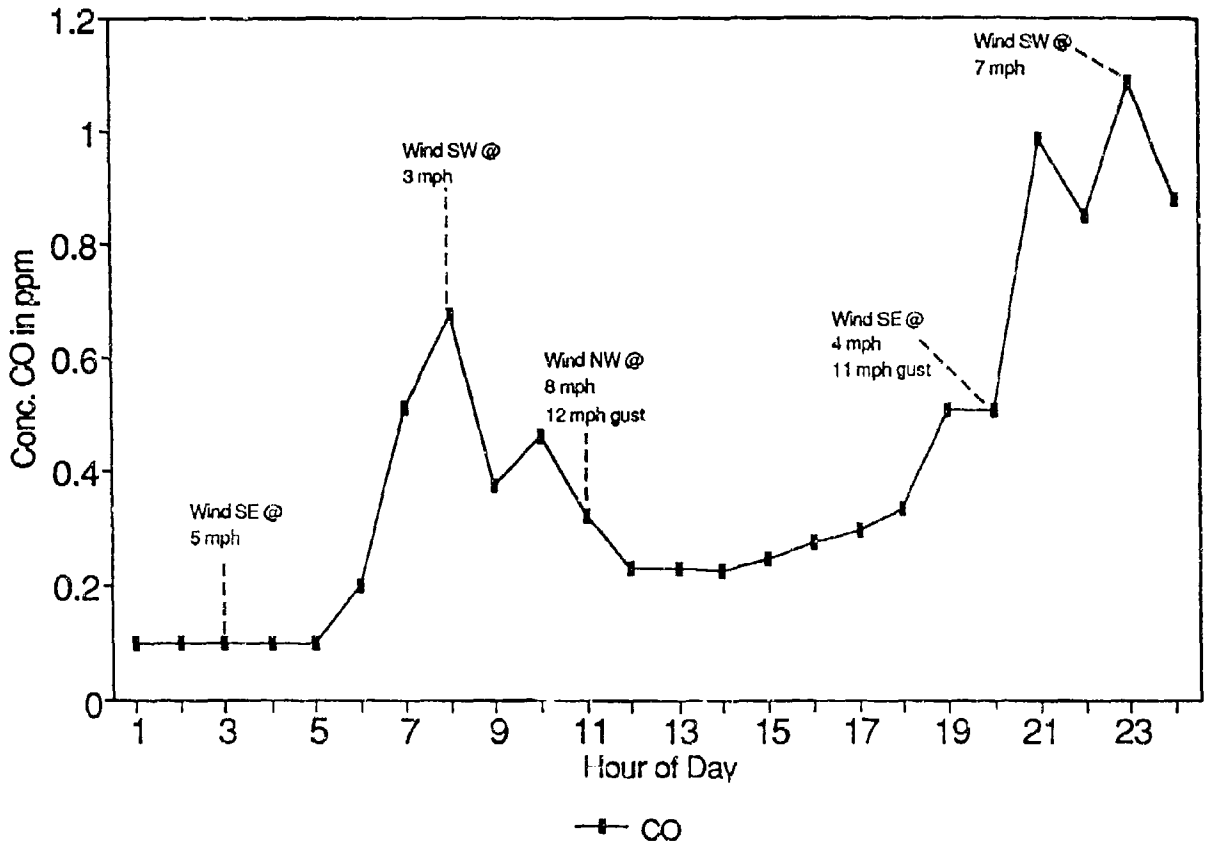
SO2 and NOx Concentrations



Prepared for : **U.S. Army Program Manager for** **Rocky Mountain Arsenal** **Commerce City, Colorado** Prepared by : **R.L. Stollar & Associates, Inc.** **Ebasco Services Inc.**	Figure 6.2-9 Brown Cloud Event : September 14, 1990 (SO_2 and NOx) **CMP AR FY90**

Brown Cloud Event: September 14, 1990

CO Concentration



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Commerce City, Colorado

Prepared by :

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Ebasco Services Inc.

Figure 6.2-10

Brown Cloud Event :

September 14, 1990

(CO)

CMP AR FY90

affected more by trapped "particulate pollution" from limited mixing regional impacts than from local gaseous pollution.

6.3 SUMMARY

This section has illustrated the interrelationship between visibility and air quality conditions at RMA, and meteorological factors that control the transport of potential pollutants within the metropolitan Denver area. Additional examples have been provided in Section 5.7 where emphasis was placed on specific point sources that impact the Arsenal. There is no single or dominant parameter that can be used to define or predict RMA air quality; however, multiple point sources and releases within the metropolitan area have the potential to impact the Arsenal. There are also local RMA remediation activities that have significance, depending upon the nature of the potential compounds which might be released during excavation. There are, in all cases, overriding meteorological influences that distribute potential pollutants both into the Arsenal and out of the Arsenal. In these studies, the CMP is attempting to identify the variable sources and influences in order that air quality data measured under the program can be evaluated in proper perspective.

7.0 METEOROLOGY MONITORING AND DISPERSION MODELING PROGRAMS

7.1 METEOROLOGY PROGRAM OVERVIEW

The meteorological program and station locations are described in Section 3.5. A modification to the program placed meteorological monitoring, maintenance and data processing and analysis under CMP esponsibilities in FY89. Complete listings of all data collected and used in this report are provided in Appendix J. Pertinent summaries of wind speed, wind direction, temperature, relative humidity, barometric pressure, solar radiation, precipitation and stability are shown in the following sections.

7.1.1 PROGRAM OBJECTIVES

The meteorological assessment has several objectives. The first is to identify atmospheric conditions associated with typical and potentially high contamination levels resulting from existing sources and remedial activity at RMA. Prevailing wind flow, wind speed, peak wind gusts, temperature and precipitation all influence the release and spread of atmospheric emissions. A meteorological database has, therefore, been established to identify typical relationships as well as to examine seasonal and diurnal effects. For example, gusty winds often will cause higher levels of total suspended particulates, inhalable particulates of less than 10 microns, metals and possibly semi-volatile organic compounds. This information is pertinent to interpreting air sampling results. Certain pollutant emissions may be more prevalent in summer than in winter which may be an important factor for remediation planning. Also, diurnal influences (such as the formation of a drainage wind pattern during nighttime and early morning inversion periods) will result in significantly higher levels of certain pollutants. This information, again, is useful in assessing the potential spread of contaminants and possible mitigating measures during remedial activities.

Another objective of the meteorological assessment is to determine the representativeness of the meteorological data with respect to associated air quality conditions. Meteorological factors change not only from season to season, but also from year to year. Variations in these elements, as noted, will influence air sampling results. A particular sampling program, a period with anomalous precipitation or drought conditions, extensive snow cover, strong winds, very warm temperatures, or even generally poor dispersion conditions will have a direct influence on pollutant levels at specific monitoring site locations. Again, this information is essential for interpreting the results. Consequently, this meteorological data will be useful in assessing remediation progress over the total period of the CMP.

In addition to the above factors, the meteorological program directly supports air quality model applications that are used in pollution dispersion evaluations and predictions. These, in turn, are employed for assessing impacts beyond the RMA boundary, or in predicting real-time pollution levels during remedial activities.

7.1.2 Data Recovery

Details of the recovery of FY90 meteorological data for each parameter of the composite database are given in Table 7.1-1. Recoveries are based on the total number of hours of possible data during the period October 1, 1989, through September 30, 1990 (8,760 hours). Temperature difference was not started until November; therefore, the total hours possible was 7,807. Observations (hourly values) were considered invalid or missing if there were less than 45 minutes of valid recorded data for that parameter or if there were equipment malfunctions or calibrations.

Table 7.1-1 Summary of RMA Meteorological Monitoring for FY90

Parameter	No. Samples	% Recovery
Wind Speed	8,734	99.7
Wind Direction	8,734	99.7
Sigma Theta	8,734	99.7
Temperature	8,760	100.0
Relative Humidity	7,814	89.2
Barometric Pressure	8,296	94.7
Solar Radiation	8,760	100.0
Precipitation	8,760	100.0
Maximum Gust	8,735	99.6
Temperature Difference (10 m - 2 m)	7,697	98.6
Stability	8,734	99.7
Program Total	**93,748**	**98.3**

7.1.3 Databases

A single, representative composite database was developed from data collected at all four RMA sites. Site M4 was the primary source for the composite database for all of FY90. Data from other sites were also used to fill in or substitute for the invalid or missing data. The amount of substituted data

is generally very small (3 percent or less). Certain parameters are taken from different sites for the composite database since no site monitors all the parameters. Relative humidity, maximum gust and temperature difference (10 m - 2 m) were from M1, and solar radiation was from M2. All other meteorological parameters were obtained from M4. Complete listings of the composite database and the associated joint frequency distributions used for this report are provided in Appendix I. The composite database provides a suitably representative sample of meteorological conditions at RMA for FY90.

Separate databases were also maintained for each site (M1, M2, M3, and M4) without any substitutions being made for missing or invalid data. These databases were used for site comparisons within the Arsenal boundary to note any areal differences. The joint frequency distributions for each site are provided in Appendix J.

All summaries shown in this report were prepared under the CMP and taken from the FY90 composite database, except for the comparison of the four meteorological sites (Section 7.5) which utilizes each of the separate databases. All data have been thoroughly checked for quality, including the substituted data. Long-term climatological Denver Stapleton Airport means (Section 2.2) were used for comparison. The FY88 and FY89 data, which were also used for comparison, are provided in Section 5.0 of the FY88 Air Quality Data Assessment Report (Stollar, 1989) and in Section 6.0 of the FY89 Air Quality Data Assessment Report (Stollar, 1990). Pertinent summaries of all of the above parameters follow.

7.2 Summary of Results

A summary of monthly and annual (October 1, 1989, through September 30, 1990) meteorological data for FY90 at RMA is provided in Table 7.2-1. All parameters summarized in this table are based on hourly averaged values with the exception of maximum gust, which is the maximum instantaneous wind speed for the period. Maximum speed is the maximum 1-hour average wind speed value for the period. The predominant wind direction indicates the sector (of 16 possible sectors) from which the wind is blowing most frequently during the reported period. Temperature difference is the difference in temperature between the 10-meter and 2-meter sensors (10 m - 2 m).

The monthly means and extremes of temperature values clearly depict the typical annual cycle, with only minor deviations from normal. The precipitation data revealed an annual cycle, but it was somewhat masked by individual events. The spring season was drier than normal while the summer

Table 7.2-1 Summary of Rocky Mountain Arsenal Monthly Meteorological Conditions for FY90 (October 1, 1989 through September 30, 1990)

	Month	Temperature (°F)					Mean Relative Humidity (%)	Mean Station Pressure (in. Hg)	Mean Total Daily Solar Radiation (Ly/Hr)	Precipitation (inches)		
		Avg Max	Avg Min	Extr Max	Extr Min	Mean				Total	Max 24-Hr	# of Days
1	Oct	63.1	39.2	81.8	18.9	51.1	39	24.76	0.24	0.29	0.19	3
2	Nov	55.1	31.5	76.2	10.1	42.7	41	24.67	0.18	0.03	0.02	2
3	Dec	38.2	17.3	67.3	-14.0	27.7	58	24.73	0.13	0.22	0.19	2
4	Jan	46.4	26.7	70.1	14.6	36.2	45	24.61	0.17	0.32	0.31	2
5	Feb	42.2	23.3	63.2	-1.3	32.4	62	24.66	0.20	0.11	0.06	2
6	Mar	48.3	29.0	67.1	12.4	38.4	50	24.67	0.26	1.97	0.81	8
7	Apr	57.6	37.5	74.8	23.6	47.5	65	24.65	0.30	0.58	0.31	8
8	May	66.5	43.1	83.3	31.3	54.9	57	24.61	0.40	1.58	0.98	7
9	Jun	85.1	57.9	98.6	45.7	71.8	38	24.67	0.49	0.28	0.28	1
10	Jul	80.4	58.6	98.0	48.6	68.9	62	24.79	0.39	2.58	0.90	14
11	Aug	82.6	58.6	94.7	51.3	69.7	50	24.80	0.39	2.42	0.98	9
12	Sep	77.2	54.8	93.4	43.7	65.4	53	24.82	0.32	1.18	0.72	9
13	Year	62.0	39.9	98.6	-14.0	50.6	52	24.71	0.29	11.56	0.98	67

AIR-TBL2.90

Table 7.2-1 Summary of Rocky Mountain Arsenal Monthly Meteorological Conditions for FY90 (October 1, 1989 through September 30, 1990) (continued)

	Month	Wind Speed (MPH)			Predominant Wind Direction	Temp Diff	Atmospheric Stability Category (% occurrence)					
		Mean Speed	Maximum Speed	Maximum Gust			A	B	C	D	E	F
1	Oct	8.0	30.1	43.8	SSW	NA	16.5	4.3	5.4	45.0	19.5	9.3
2	Nov	9.2	27.5	37.6	SSW	2.3	11.0	2.6	3.6	53.5	17.5	11.8
3	Dec	8.0	27.6	38.7	SSW	1.8	7.5	3.1	6.6	50.5	21.0	11.3
4	Jan	9.7	31.4	46.6	SSW	2.0	8.6	3.6	4.7	55.2	17.2	10.6
5	Feb	8.6	29.7	40.0	SSW	1.3	8.3	2.7	6.3	50.6	19.8	12.4
6	Mar	7.9	35.9	43.1	SSW	1.1	14.6	6.0	5.6	42.1	19.4	12.3
7	Apr	8.5	30.1	43.1	SSW	0.7	17.0	6.8	6.0	43.8	14.5	12.0
8	May	9.6	35.5	52.8	SSW	0.6	18.2	6.7	6.2	50.1	10.2	8.6
9	Jun	9.9	29.4	44.6	SSW	0.6	24.3	5.3	3.9	46.9	12.2	7.4
10	Jul	8.0	23.3	40.2	SOUTH	0.1	24.3	5.9	7.5	36.4	13.6	12.2
11	Aug	8.0	26.4	45.1	SSW	0.6	23.9	7.5	5.7	38.4	15.7	8.7
12	Sep	7.5	25.6	49.4	SSW	0.6	22.9	3.9	6.4	36.5	20.7	9.6
13	Year	8.6	35.9	52.8	SSW	1.0	16.5	4.9	5.7	45.8	16.8	10.5

Legend: Maximum Speed = Maximum 1-Hr Average Wind Speed Value for the Month
Maximum Gust = Maximum Instantaneous Wind Speed for the Month
Temp Diff = Temperature Difference (10-meter minus 2-meter) on the Tower

A = Extremely Unstable
B = Unstable
C = Slightly Unstable
D = Neutral
E = Stable
F = Extremely Stable

was moist. Wind speed data showed the strongest winds during the spring months, but the maximum gusts were clearly dominated by single events. The predominant wind direction during FY90 was from the south-southwest, which was slightly different from the expected prevailing pattern of southerly winds. Stability patterns showed a maximum of stable conditions in the fall and winter and a maximum of unstable conditions in the spring and summer. A neutral stability condition prevailed during all months with almost half the total frequency of occurrence.

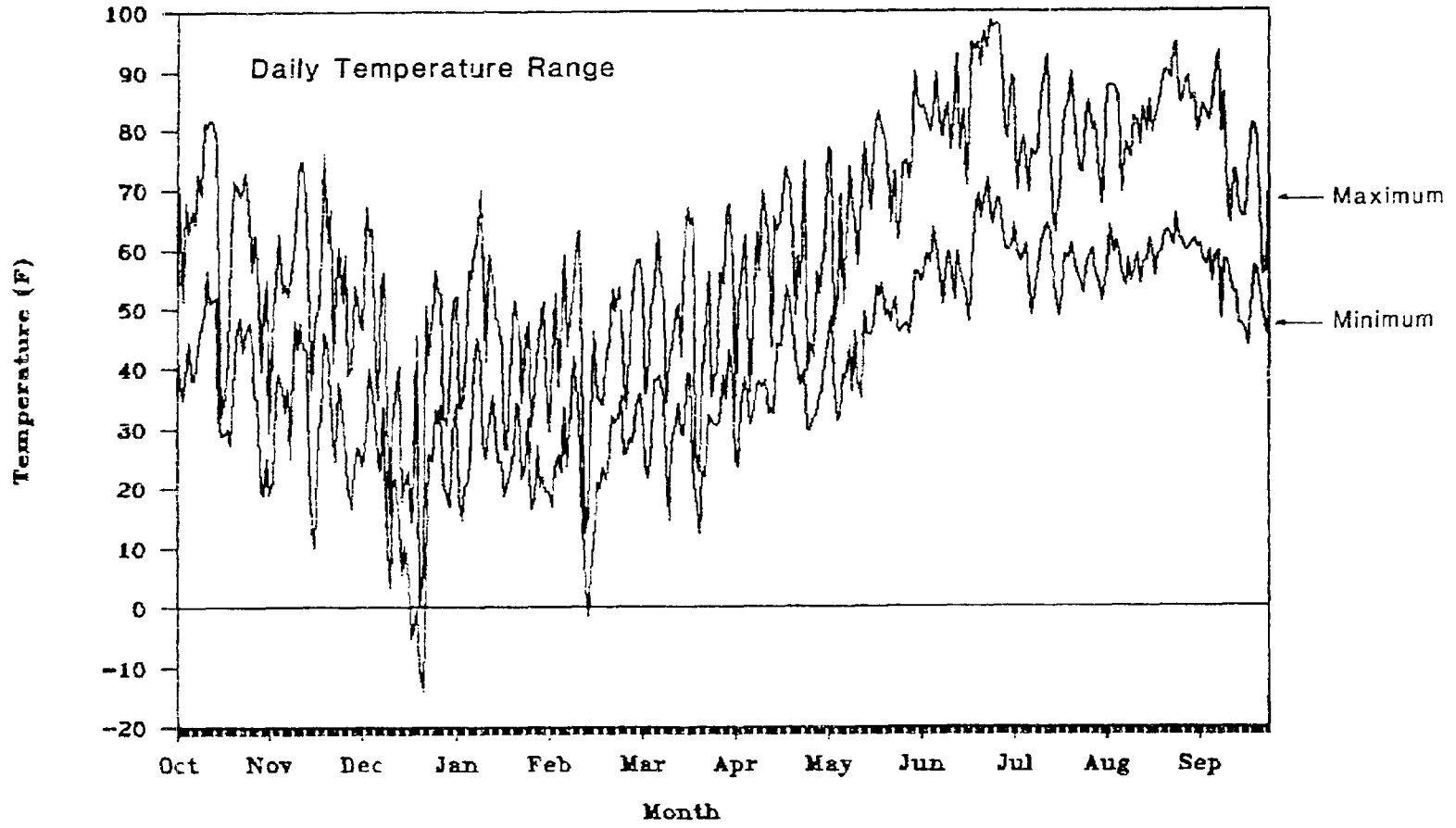
The parameters are discussed in more detail below. Included are discussions of FY90 conditions in comparison to FY88 and FY89 data (where applicable) and to the long-term climatology at Stapleton Airport. Also, specific conditions, extreme events, and anomalous conditions are described for each parameter.

7.2.1 TEMPERATURE

The RMA FY90 annual mean temperature, 50.6°F, was very close to normal. The year itself was near or slightly warmer than normal with only minor deviations. The summer months of July and August were somewhat cooler (4.4°F and 1.7°F below normal, respectively) associated with increased rainfall. January was somewhat warmer at 6.7°F above normal. The maximum monthly average was 71.8°F in June and the minimum monthly average was 27.7°F in December. The maximum temperature, 98.6°F, was recorded in June during a short heat wave, and the minimum temperature, -14.0°F, was recorded in December during a cold wave. This cold wave came in December as opposed to February in FY89. The time series of daily maximum and minimum temperature through the FY90 program is shown in Figure 7.2-1, indicating the extreme events and the day-to-day variability in temperature.

7.2.2 RELATIVE HUMIDITY

The annual mean relative humidity, 52 percent, was near normal. All months followed quite closely to normals with higher values in the winter and spring due to lower temperatures and increased amounts of precipitation, and lower values in the summer and fall due to higher temperatures. The maximum monthly average was 65 percent in April and the minimum monthly average was 39 percent in October.



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Rocky Mountain Arsenal
Commerce City, Colorado
Prepared by :
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Figure 7.2-1

RMA Graphical Depiction of Temperature
(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

7.2.3 Barometric Pressure

The annual mean station barometric pressure, 24.71 inches of mercury (in. Hg), was almost identical to long-term normals. All months followed the normals quite closely. The maximum monthly average was 24.82 in. Hg in September and the minimum monthly average was 24.61 in. Hg in January and May.

7.2.4 Solar Radiation

The solar radiation values included nighttime values to show the increase in solar radiation in the spring and summer due to the length of the days. The annual mean solar radiation was 0.29 langleys per hour (ly/hr). This value was higher than that of FY89 (0.24 ly/hr). Values were slightly higher in the summer with lower values in the winter. The maximum monthly average was 0.49 ly/hr in June and the minimum monthly average was 0.13 ly/hr in December. The RMA area generally has an abundance of sunshine throughout the year, as was evident in FY89 and FY90.

7.2.5 Precipitation

Precipitation for the FY90 period from October 1, 1990, through September 30, 1990, totaled 11.56 inches at RMA, compared with the climatological mean of 15.31 inches or 3.75 inches below normal. Stapleton Airport data for FY90 was much closer to normal. The lower amount at RMA may, in part, be due to winter readings, when snow blows away before it can be measured. The spatial variability associated with summertime thundersturm activity may also account for this difference. During the colder seasons, precipitation was primarily in the form of snow with a total of 62.2 inches falling in 55 days. A major snowstorm occurred on March 6, reflecting the elevated total of 1.97 inches of precipitation for that month. The heaviest monthly precipitation total, 2.58 inches, was measured during July. The month of May generally records the heaviest precipitation, with a long-term mean of 2.47 inches and an all-time maximum of 7.31 inches. However, in FY90, summertime heavy precipitation events accounted for higher levels in July and August; several storms were intense and stagnated over the area, allowing the majority of the monthly precipitation to be recorded in 1 or 2 days.

The rest of the FY90 monitoring period was normal to drier than normal. The driest month was November with only 0.03 inches. A time series of daily total precipitation during the FY90 program is shown in Figure 7.2-2. Heavier precipitation events in the spring and summer are highlighted.

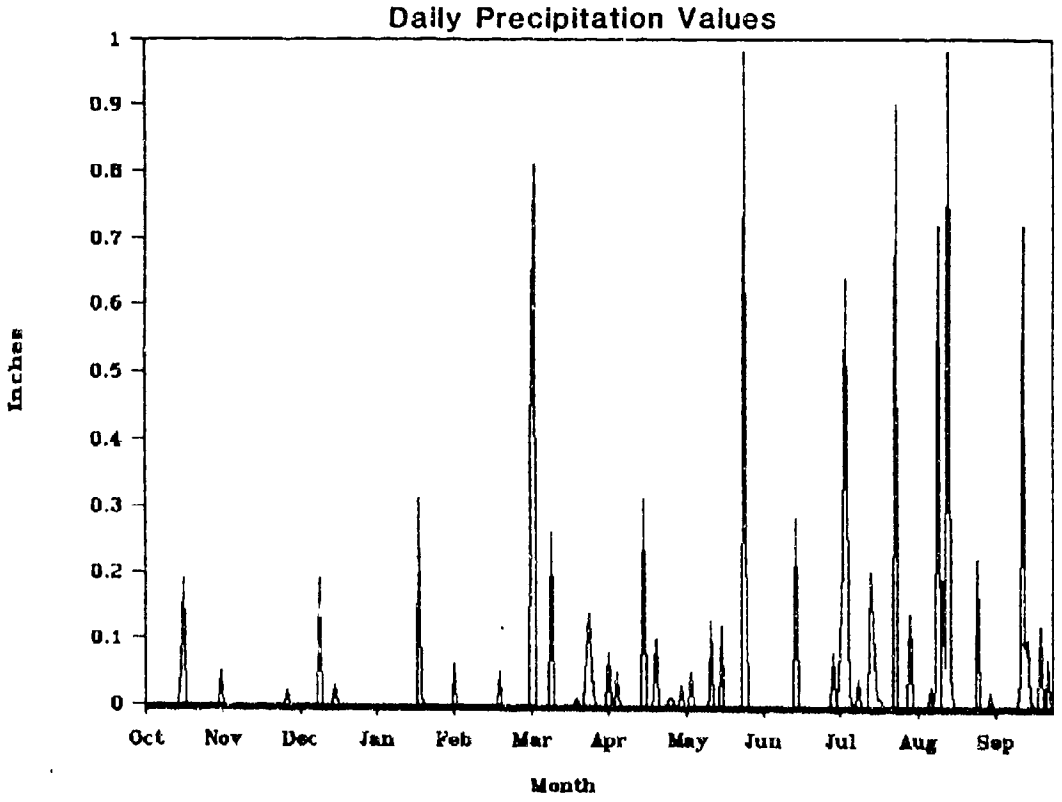

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Figure 7.2-2

RMA Graphical Depiction of Precipitation
(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

Also, it can be seen that total monthly precipitation was often a reflection of one or a small number of heavy rainfall events.

7.2.6 WINDS

Hourly mean wind speeds for the entire CMP FY90 program averaged 8.6 mph compared to a 30-year climatological mean value (at Stapleton Airport) of 8.8 mph. This close comparison is important because pollutant levels, especially those associated with dust particles (i.e., TSP, PM-10, metals and SVOCs) are sometimes generated by high wind speeds. The data show that FY90 mean wind speeds were close to average for all months. The maximum monthly average was 9.9 mph in June and the minimum monthly average was 7.5 mph in September. The maximum gust, 52.8 mph, was recorded in May. The predominant wind direction for the RMA in FY90 was south-southwest, compared to the Stapleton Airport 30-year record of south. In FY90, the RMA had a predominant south-southwest wind for all months except July, when the predominant wind was from the south. During FY88 and FY89, predominant winds were more variable from month-to-month; however, the long-term normal was southerly. As noted in Section 5, the slight shift of predominant winds at RMA in FY90 from south to south-southwest may have accounted for slightly higher criteria pollutant levels at RMA. The time series of daily mean wind speeds, maximum gusts, and predominant wind directions during the program are shown in Figure 7.2-3.

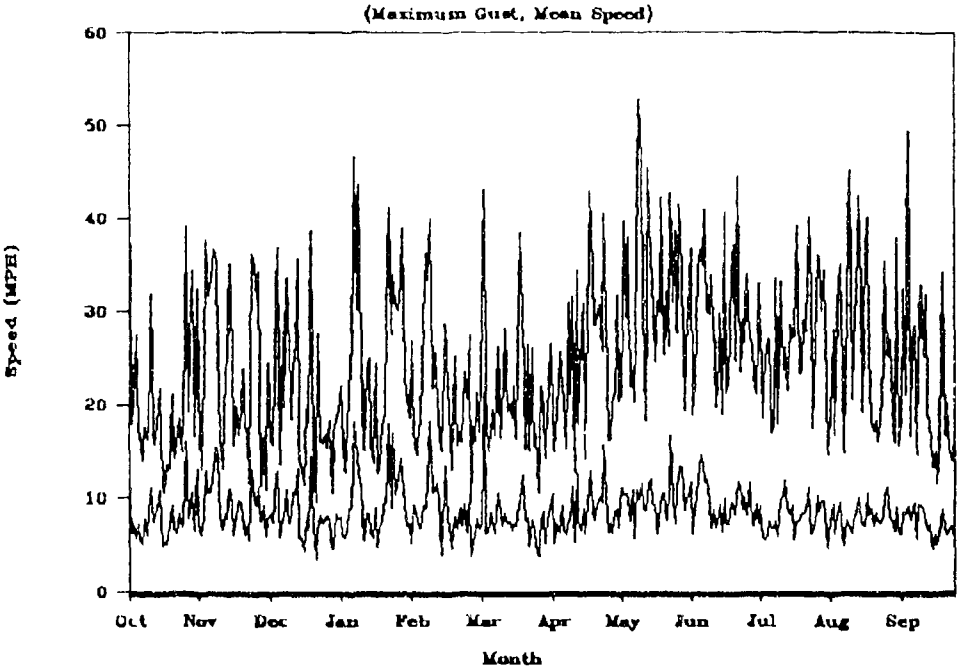
There was a slight disparity between the 5-year seasonal and annual wind roses for Stapleton Airport and the corresponding wind roses for the CMP FY90 monitoring periods shown in Figures 7.2-4 through 7.2-8. The CMP FY90 wind roses showed tendencies for a strong south-southwest to north-northeast flow, whereas, south to north is the most common flow pattern at Stapleton Airport. The secondary component was north-northeast at RMA, compared to northerly for the long-term normals. The FY90 wind patterns were close to normal patterns in all other directions.

7.2.7 ATMOSPHERIC STABILITY

Atmospheric stability is an important parameter relating to the dispersion of air pollutants. Along with wind speed and wind direction, it is a key parameter in air quality dispersion models and reflects the potential of the atmosphere to diffuse pollutants horizontally and vertically. Table 7.2-1 shows the frequency distribution for all atmospheric stability categories A through F during the CMP monitoring period. A full joint frequency distribution (JFD) of wind speed, wind direction and stability is provided in Appendix J. Categories A, B and C, which indicate good dispersion or

Daily Wind Speed Values FY90

(Maximum Gust, Mean Speed)



Daily Predominant Wind Direction FY90

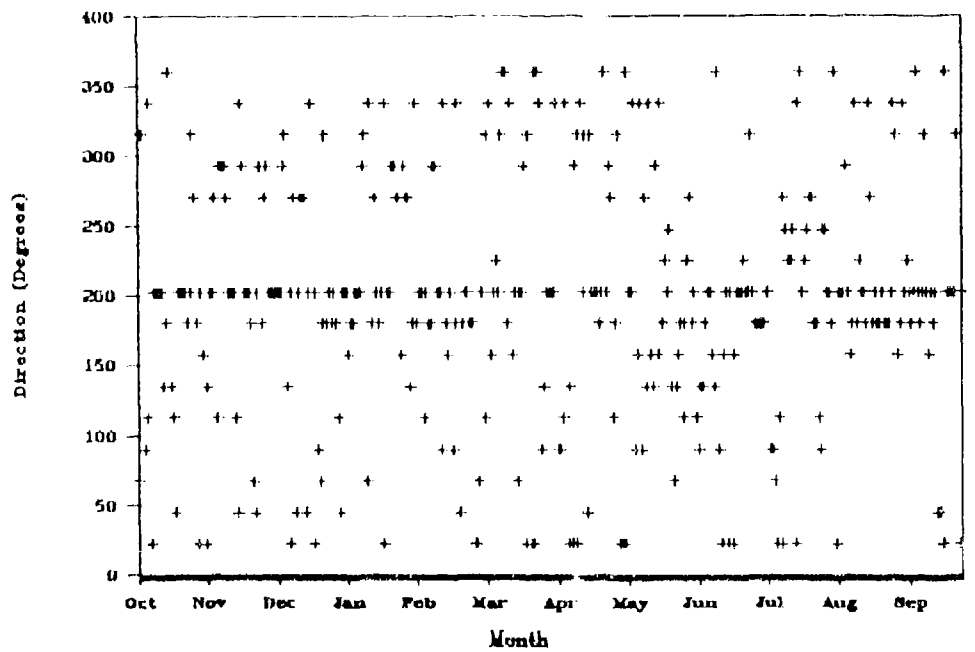


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Figure 7.2-3

RMA Graphical Depiction of
Wind Speed and Wind Direction
(Oct. 1, 1989-Sept. 30, 1990)

CMP AR FY90

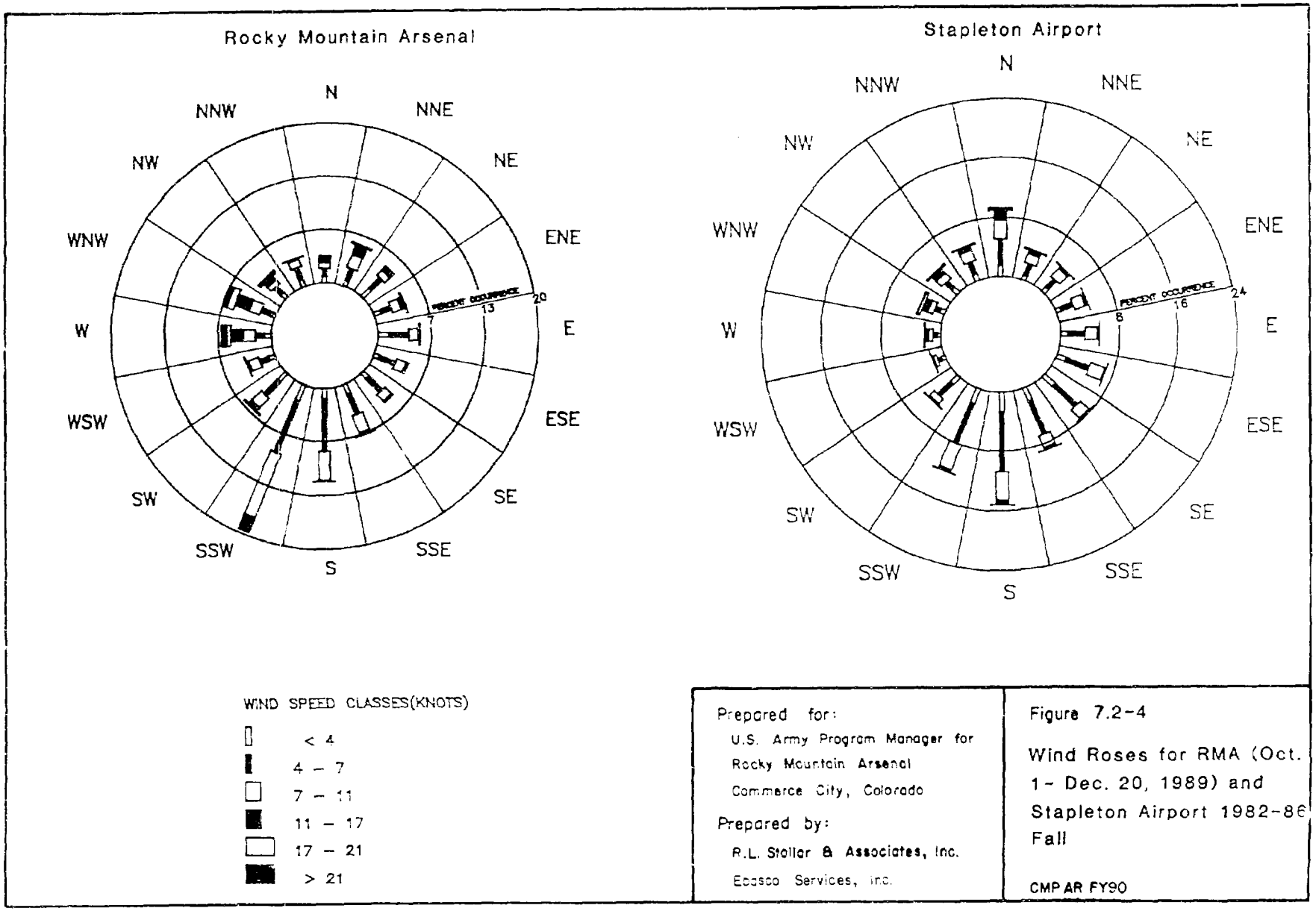

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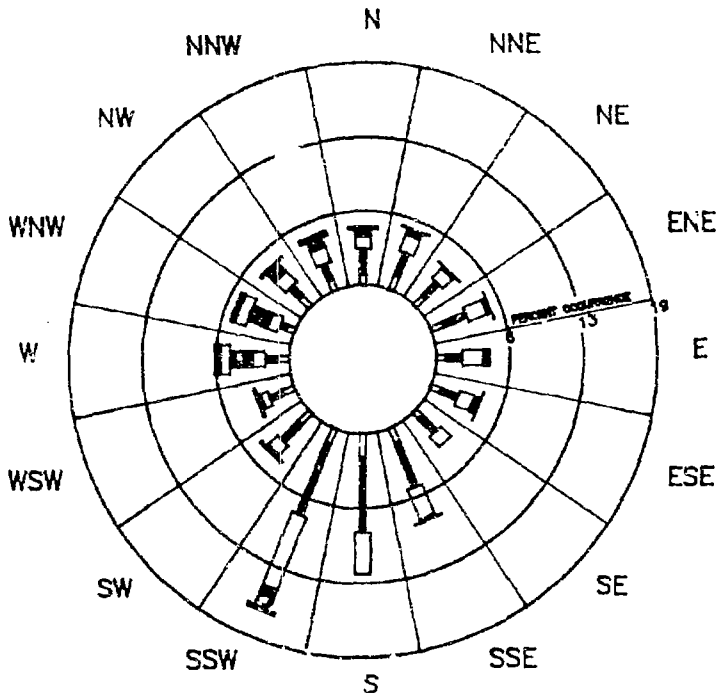
Figure 7.2-4

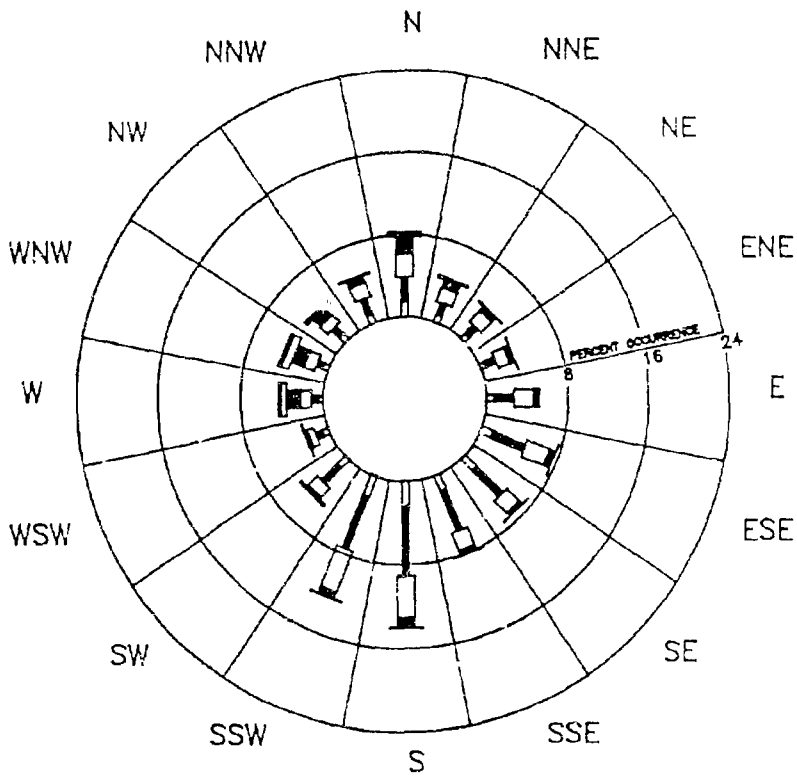
Wind Roses for RMA (Oct. 1 - Dec. 20, 1989) and Stapleton Airport 1982-86 Fall

CMP AR FY90

Rocky Mountain Arsenal



Stapleton Airport



WIND SPEED CLASSES(KNOTS)

- < 4
- 4 – 7
- 7 – 11
- 11 – 17
- 17 – 21
- > 21

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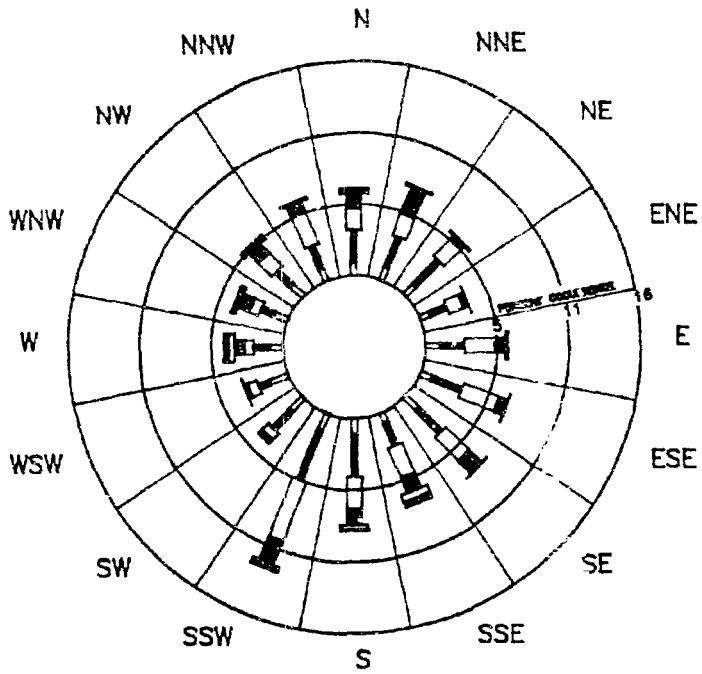
Figure 7.2-5

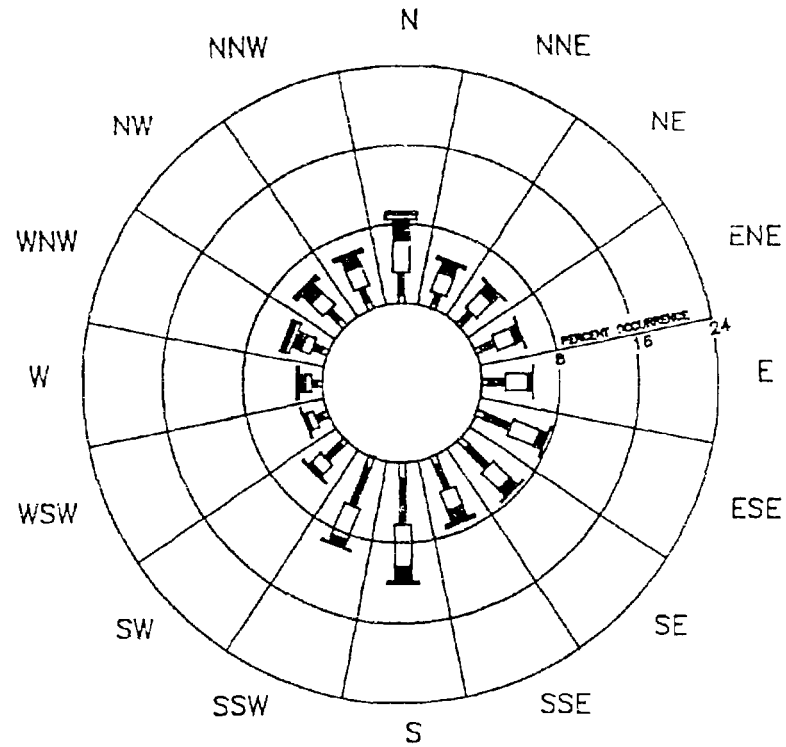
Wind Roses for RMA (Dec. 21, 1989-March 19, 1990) and Stapleton Airport 1982-86 Winter

CMP AR FY90

Rocky Mountain Arsenal



Stapleton Airport



WIND SPEED CLASSES(KNOTS)

- < 4
- 4 – 7
- 7 – 11
- 11 – 17
- 17 – 21
- > 21

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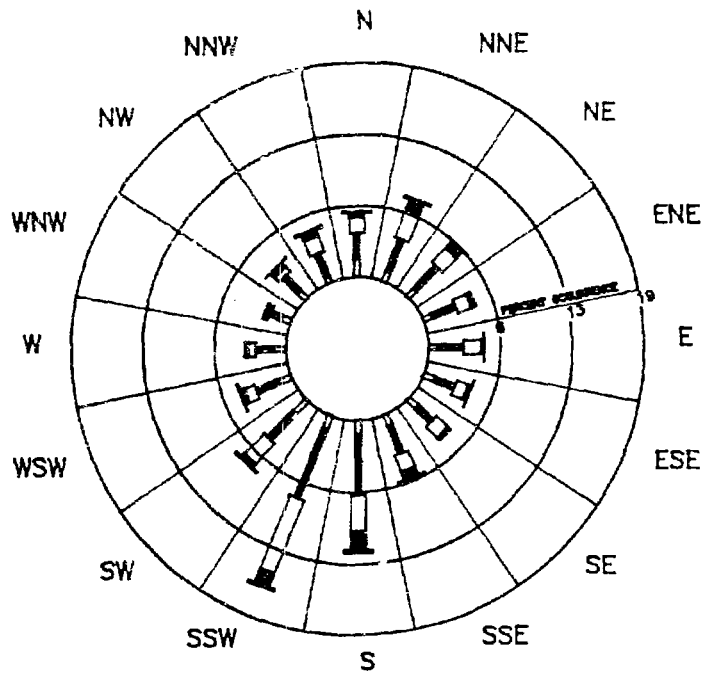
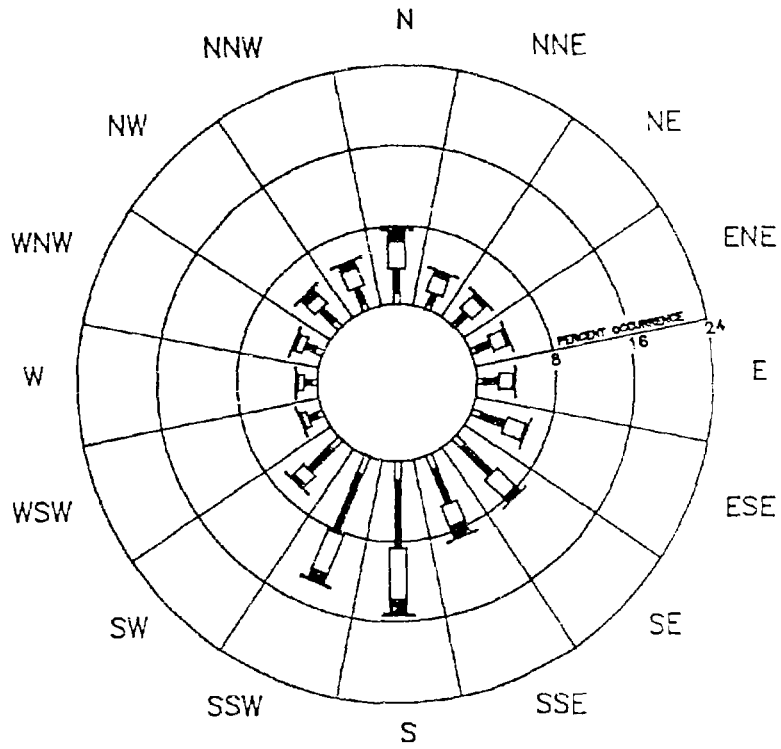
Figure 7.2-6
Wind Roses for RMA
(March 20-June 20, 1990)
and Stapleton Airport
1982-86 Spring

CMP AR FY90

Rocky Mountain Arsenal



Stapleton Airport



WIND SPEED CLASSES(KNOTS)

- < 4
- 4 – 7
- 7 – 11
- 11 – 17
- 17 – 21
- > 21

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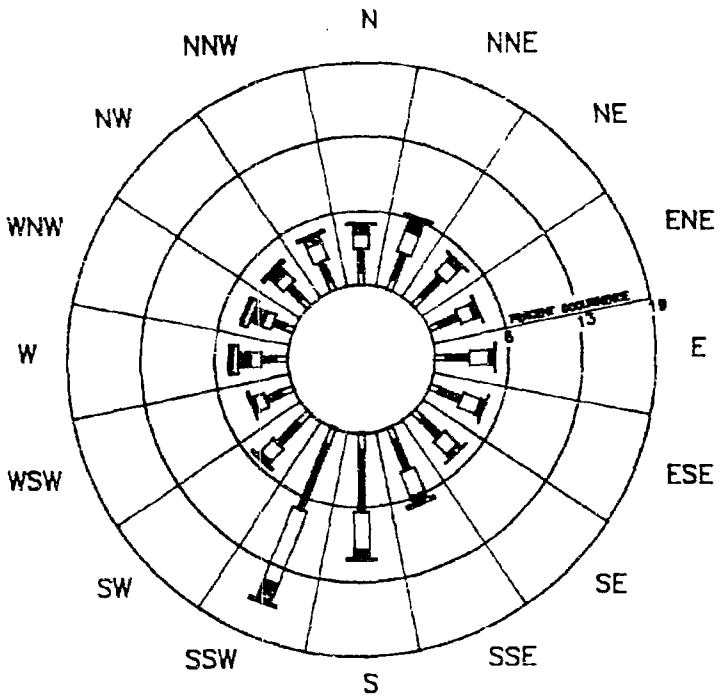
Figure 7.2-7

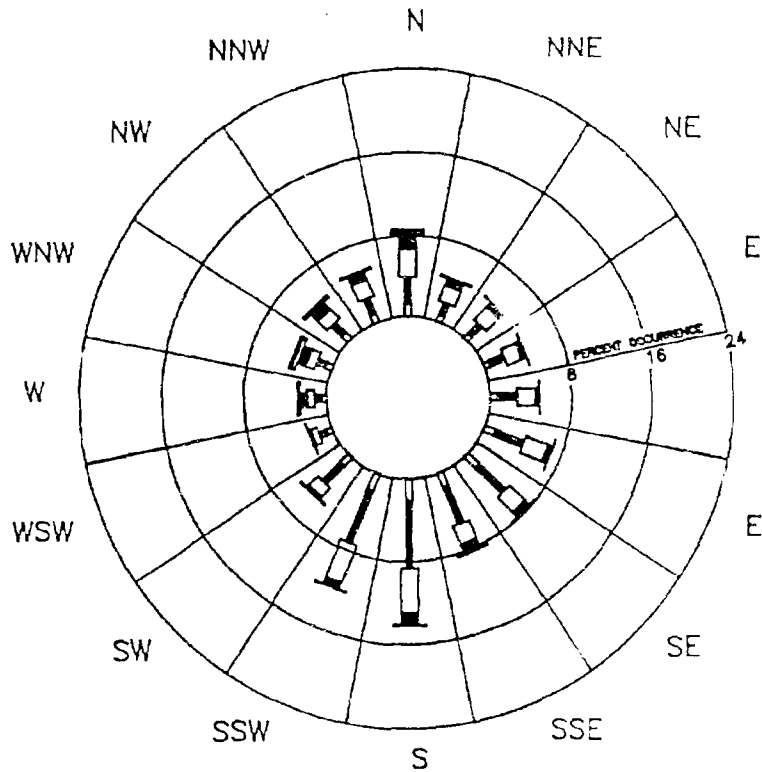
Wind Roses for RMA (June 21-Sept. 30, 1990) and Stapleton Airport 1982-86 Summer

CMP AR FY90

Rocky Mountain Arsenal



Stapleton Airport



WIND SPEED CLASSES(KNOTS)

- < 4
- 4 – 7
- 7 – 11
- 11 – 17
- 17 – 21
- > 21

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Figure 7.2-8

Wind Roses for RMA (Oct. 1, 1989-Sept. 30, 1990) and Stapleton Airport 1982-86 Annual

CMP AR FY90

"unstable" conditions and occur primarily during midday and afternoon periods and most often in the warmer seasons, were measured 16.5, 4.9 and 5.7 percent of the time respectively, or a total of 27.1 percent of the time. Categories E and F, which reflect poor dispersion or "stable" conditions and occur during morning hours and more often in the colder seasons, were measured 16.8 and 10.5 percent of the time, or a total of 27.3 percent. The remainder of the cases, 45.8 percent, were in category D, which reflects neutral atmospheric or moderate to strong wind conditions (a frequent occurrence at RMA). Generally dispersion conditions are good under D stability, although as noted in this report, strong winds also have the potential of increasing the emissions of dust-associated particles.

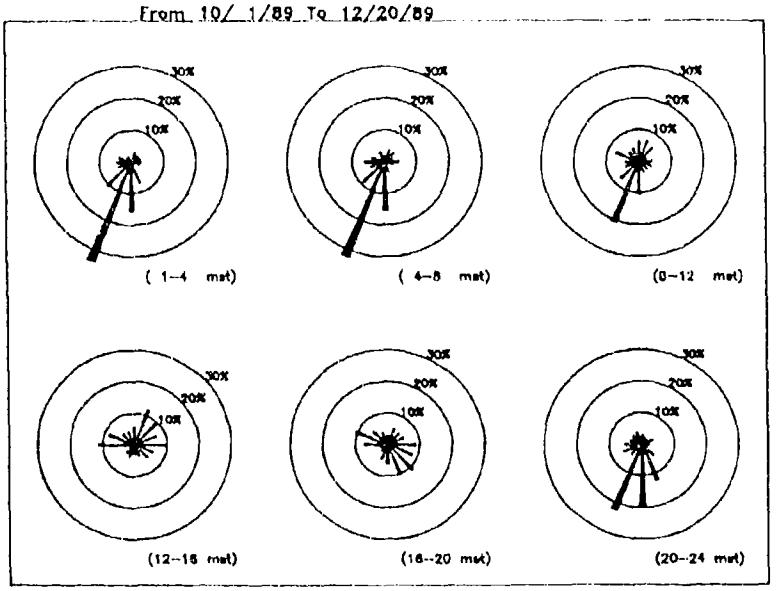
Another indicator of stability is the temperature difference between the 10-meter and 2-meter levels. Greater average temperature differences were recorded in the colder seasons (more stable) compared to smaller differences in the summer (more unstable or neutral).

The stability data for FY90 appear to be typical of the Denver area. The inversion conditions associated with poor dispersion categories E and F were less frequent during the spring and summer and occurred primarily in the nighttime and early morning periods. During the winter there were many inversion periods that lasted continuously for several days and intensified the "brown cloud" over the Denver area. During spring and summer the dispersion potential was more typically bimodal, with excellent dispersion during the day and poor dispersion at night.

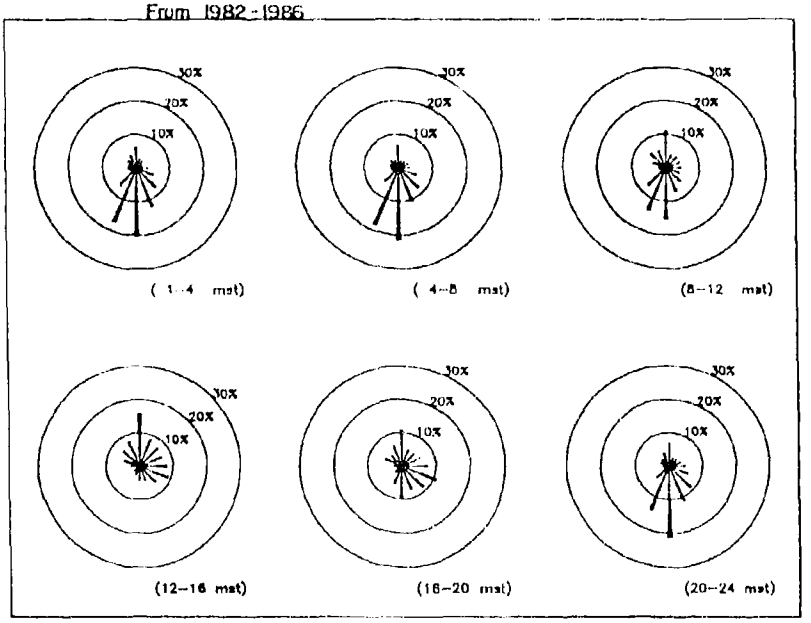
7.3 SEASONAL AND DIURNAL INFLUENCES

Dispersion characteristics are closely related to diurnal cycles in atmospheric stability and wind patterns. During the daytime when dispersion conditions are good (Categories A, B and C), winds are highly variable and frequently gusty. At night when the inversions set in and dispersion is poor (Categories E and F), winds are generally light and follow a drainage pattern from south to north. The seasonal drainage influence is reflected in monthly stability distributions (Table 7.2-1). For example, stable categories E and F occurred 33 percent of the time in December and 20 percent in June during FY90. Nevertheless, drainage can be expected in all seasons of the year. These patterns are also reflected in seasonal and annual FY90 RMA and long-term (5-year Stapleton Airport) wind roses for separate periods of the day as illustrated in Figures 7.2-9 through 7.2-13. The south-southwesterly flow experienced at RMA during FY90 is evident. All seasons resemble one another, which is typical of the Denver area. The FY90 RMA diurnal wind roses showed a predominance of south-southwesterly flow during the midnight to 8 A.M. period; from 8 A.M. to noon there was a

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 10/ 1/89 To 12/20/89



DENVER STAPLETON FALL DIURNAL WIND ROSES
From 1982-1986



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Commerce City, Colorado

Prepared by :
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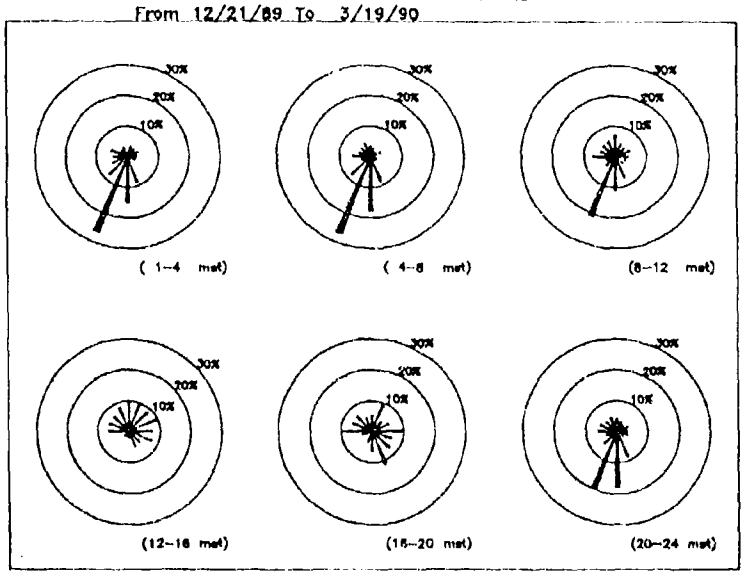
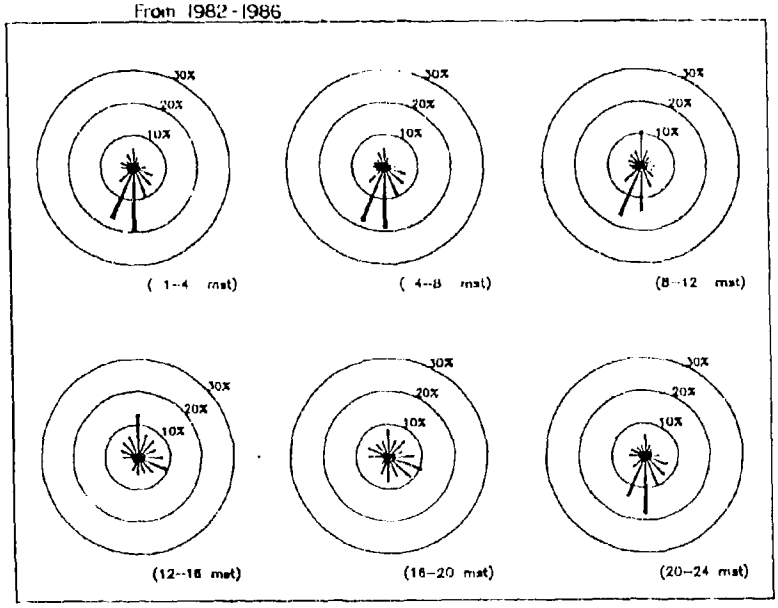
Figure 7.2-9
RMA and Stapleton Airport
Fall Wind Rose
Comparisons

CMP AR FY90

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 12/21/89 To 3/19/90



DENVER STAPLETON WINTER DIURNAL WIND ROSES
From 1982-1986



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Commerce City, Colorado
Prepared by :
R.L. Stollar & Associates, Inc.
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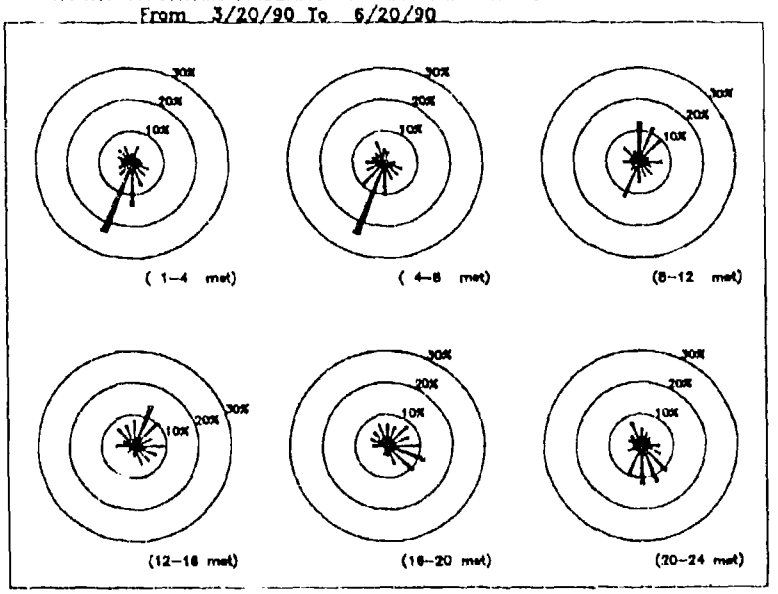
Figure 7.2-10
RMA and Stapleton Airport
Winter Wind Rose
Comparisons

CMP AR FY90

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 3/20/90 To 6/20/90



DENVER STAPLETON SPRING DIURNAL WIND ROSES
From 1982-1986

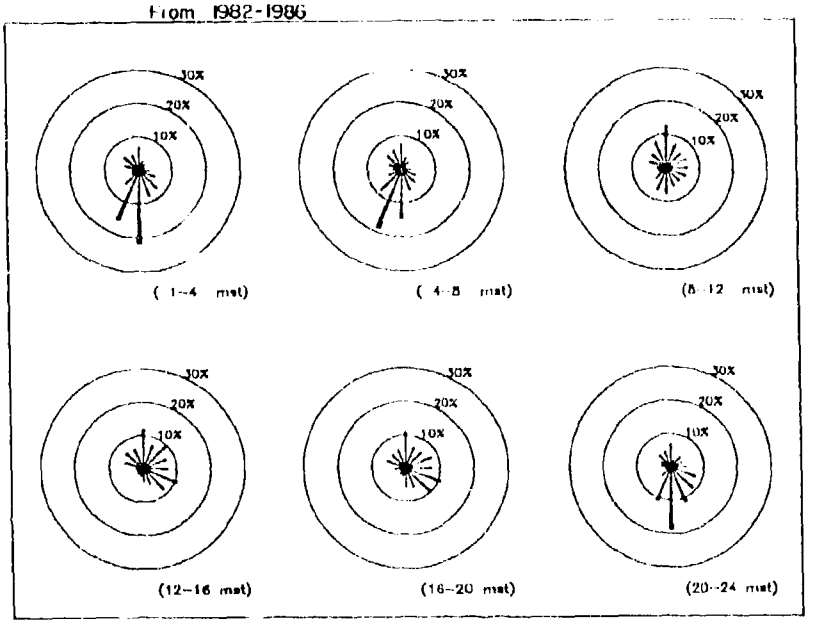


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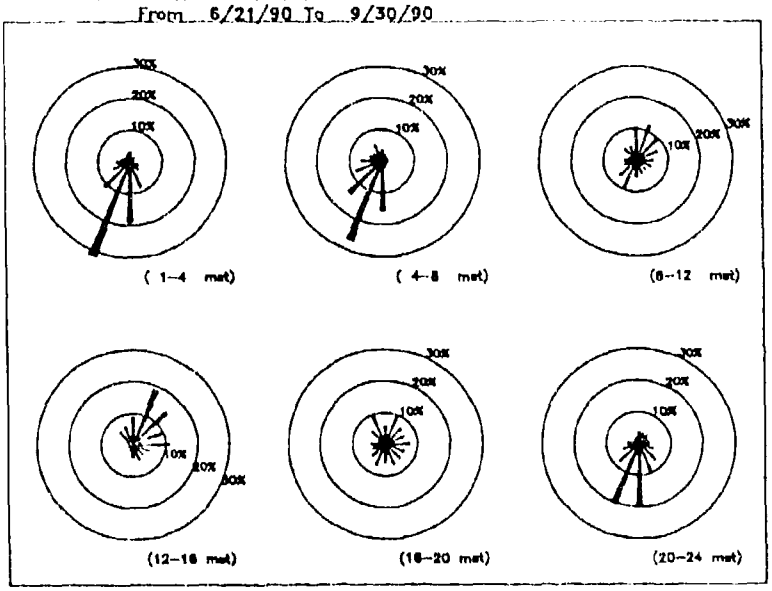
Figure 7.2-11

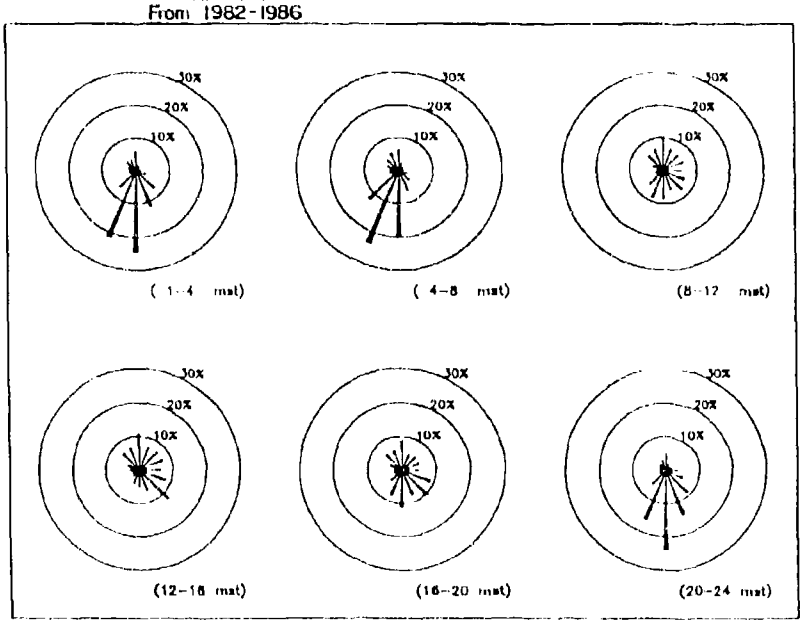
RMA and Stapleton Airport
Spring Wind Rose
Comparisons

CMP AR FY90

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 6/21/90 To 9/30/90



DENVER STAPLETON SUMMER DIURNAL WIND ROSES
From 1982-1986



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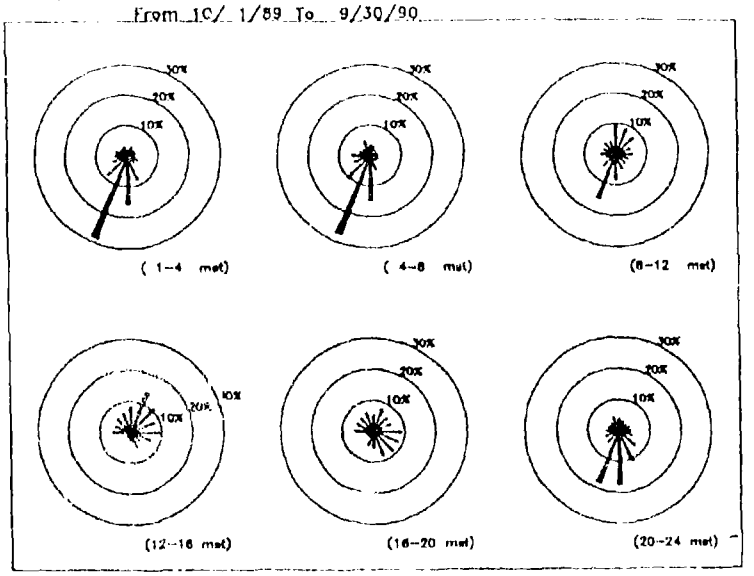
[illegible] & Associates, Inc.
Ebasco Services, Inc.

Figure 7.2-12

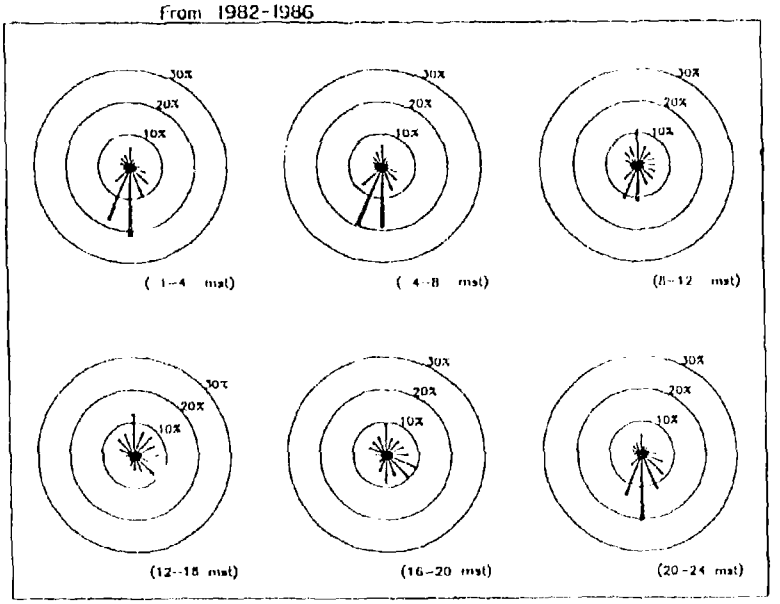
RMA and Stapleton Airport
Summer Wind Rose
Comparisons

CMP AR FY90

ROCKY MOUNTAIN ARSENAL DIURNAL WIND ROSES
From 10/ 1/89 To 9/30/90



DENVER STAPLETON ANNUAL DIURNAL WIND ROSES
From 1982-1986



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Ebasco Services, Inc

Figure 7.2-13
RMA and Stapleton Airport
Annual Wind Rose
Comparisons
CMP AR FY90

slight transition, but southwesterly flow still prevailed; from noon until 8 P.M., however, winds were highly variable, with perhaps slightly more flow from easterly components; 8 P.M. to midnight was a transition period, with the winds beginning to shift from southeast back to south-southwest.

The representativeness of the FY90 diurnal wind patterns is illustrated by a close comparison with the long-term diurnal wind roses. FY88 and FY89 diurnal wind roses were also comparable to the long-term diurnal patterns.

7.4 SUMMARY AND CONCLUSIONS

Although mean weather patterns change from year to year, it appears that the FY90 meteorological data, with minor differences, were representative of long-term data and provide a useful instrument for assessing contamination impacts during this period and for future remedial progress evaluations. Table 7.4-1 provides a comparison of FY90 meteorological parameters with those of FY89. The only differences of note were a shift in the predominant wind direction from south in FY89 to south-southwest in FY90, a maximum wind gust of 72.5 mph in FY89 compared to 52.8 mph in FY90, and a solar radiation level of 0.24 ly/hr in FY89 compared to 0.29 ly/hr in FY90. The solar radiometer was out of operation for a period during the summer of 1989, which may account for the annual differences for that parameter.

The data also suggest important guidelines for mitigation that may be appropriate during remedial activities. Emissions from daytime activities would contribute lesser impacts than nighttime and early morning activities because there are better and more variable dispersion conditions during the day. At night, inversions are prevalent and dispersion conditions are poor. Also winds at night are channelled north and northeast of the remediation source. A factor that should be taken into account, therefore, is the distance from a remediation source to sensitive areas north of the Arsenal, such as public roads and residential areas beyond RMA boundaries. However, dispersion potential apparently decreases significantly with distance from a ground emissions source and depends upon meteorological conditions.

In this section, typical impacts were inferred based on seasonal and diurnal meteorology. For real-time applications or for short-term and long-term assessments, these influences must be incorporated into atmospheric dispersion models along with detailed source emission characteristics. Model

Table 7.4-1 FY89 - FY90 Comparison

	FY90	FY89
Average Maximum Temprature (°F)	62.0	61.7
Average Minimum Temperature (°F)	39.9	38.6
Mean Temperature (°F)	50.6	49.9
Mean Relative Humidity (%)	52	49
Mean Total Daily Solar Radiation (Ly/Hr)	0.29	0.24
Total Precipitation (in)	11.56	12.41
Total Number of Days of Precipitation	67	77
Mean Wind Speed (mph)	8.6	8.5
Maximum Wind Speed (mph)	35.9	33.2
Maximum Wind Gust (mph)	52.8	72.5
Predominant Wind Direction	SSW	SOUTH
Atmospheric Stability Class (%)		
A	16.5	16.5
B	4.9	5.2
C	5.7	6.0
D	45.8	46.0
E	16.8	15.6
F	10.5	10.6

approaches employed in the present report and recommended for future remedial progress evaluations are discussed in Section 7.6.1.

7.5 RMA Meteorological Station Comparisons

During FY90, at the request of PMRMA, a special comparison was made between the data compiled at the four meteorological stations operating at RMA. Figure 3.5-1, previously shown, indicates the locations of these stations. In general, the terrain across the Arsenal is fairly uniform. Nevertheless, there are slight differences in elevation and surrounding topography that could affect air quality dispersion characteristics on certain occasions. Met Station 4 is the highest station located on the crest of a knoll at 5,278 ft. Met 1, just to the east of the old Basin F, is the lowest station at an elevation of 5,192 ft. Met Station 2 located to the north of North Plants is at an elevation of 5,193 ft, but separated from Met 1 by higher topography. Met Station 3 is located southeast of Basin A and northeast of the South Plants at an elevation of 5,263 ft. Channelling of winds around topography and temperature differences, due to drainage and elevation differences, are the main variations between the sites. (Met stations 1 through 4 are identified as M1 through M4 in Figure 3.5-1.)

Tables 7.5-1 through 7.5-3 provide a comparison of the four stations for wind speed, wind direction, temperature and precipitation from February 1989 (when the meteorological program under CMP was initiated) to the conclusion of the FY90 period in September 1990. It should be noted that certain periods of data are missing or invalid due to calibrations or tower work. These data were not included in the tower summaries. Also, the temperature sensor at Met Site 1 has a tendency to be slightly warmer due to the sensor construction; Table 7.5-2 indicates temperatures at Met 1 were an average of 1°F higher. Overall, only minor differences were noted between the stations.

The highest average FY90 wind speed of 8.7 mph occurred at Met 4, which is at the highest elevation and is the most openly exposed station in the network. The lowest average FY90 wind speed, 7.6 mph, was at Met 3. Average FY90 wind speeds at Met 1 and Met 2 were 8.2 and 7.9 mph, respectively.

The predominant wind direction at all stations was from the south-southwest with the exception of Met Station 2 where the predominant wind direction was from the south. This is a reflection of the slightly higher topography to the southwest of Met 2, illustrating how very modest topography differences can impact wind flow patterns. Channelling of winds around this terrain often results in winds from the south rather than southwest at Met 2.

Table 7.5-1 Meteorological Tower Comparison of Wind Speed (mph)/Direction

	Site 1		Site 2		Site 3		Site 4	
AVERAGE								
FEB 1989	7.1	ENE	6.7	NNE	6.5	ENE	NA	NA
MAR	9.2	S	8.8	ESE	8.5	S	NA	NA
APR	9.9	SSW	10.0	SE	9.6	SSW	NA	NA
MAY	9.2	SSW	8.9	S	8.7	SSW	9.1	SSW
JUN	8.4	SSW	6.9	SSE	7.9	SSW	8.0	NNW
JUL	8.8	SSW	NA	NA	8.3	S	8.8	SSW
AUG	8.1	SSW	5.3	N	7.7	SSW	8.1	SSW
SEP	8.3	S	7.6	SSW	7.7	SSW	8.5	SSW
OCT	7.7	SSW	7.4	S	7.1	SSW	8.0	SSW
NOV	8.2	SSW	8.4	S	8.0	SSW	9.2	SSW
DEC	7.8	SSW	7.3	S	7.0	SSW	8.0	SSW
JAN 1990	9.2	SSW	8.8	S	8.6	SSW	9.7	SSW
FEB	8.1	SSW	7.9	S	7.6	NA	8.6	SSW
MAR	7.5	SSW	7.3	N	7.0	N	7.9	SSW
APR	8.0	SSW	7.9	SSW	7.7	SSW	8.5	SSW
MAY	8.8	SSW	8.7	SSE	8.5	SSW	9.6	SSW
JUN	9.6	SSW	9.3	SSW	8.8	SSW	10.8	SSW
JUL	7.7	SSW	7.5	S	7.0	SSW	8.0	S
AUG	7.9	SSW	7.6	SSW	6.8	SSW	8.0	SSW
SEP	7.5	SSW	7.0	SSW	6.5	SSW	7.5	SSW
FY90	8.2	SSW	7.9	S	7.6	SSW	8.7	SSW
FASTEST GUST								
FEB 1989	22.9	WNW	33.6	WSW	39.8	WNW	NA	NA
MAR	32.6	WNW	53.3	SSW	49.5	WNW	NA	NA
APR	31.3	W	45.3	SSW	45.1	WNW	NA	NA
MAY	31.9	NNE	51.5	NNW	50.9	NW	33.2	NNE
JUN	27.7	E	41.0	N	42.6	E	30.4	ESE
JUL	27.8	ESE	NA	NA	54.0	SSW	27.5	SE
AUG	23.5	S	86.5	NNW	72.5	SE	24.9	SSE
SEP	24.1	NNE	32.2	NNE	41.6	SSE	24.9	SSW
OCT	48.3	SSE	43.8	WNW	43.8	WNW	30.1	WNW
NOV	36.3	W	38.8	W	37.6	W	27.5	W
DEC	38.7	WNW	38.5	NW	37.3	NW	27.6	WNW
JAN 1990	46.6	NW	44.9	NW	47.8	NW	31.4	WNW
FEB	40.0	WNW	36.4	WNW	40.1	NA	29.6	W
MAR	43.1	N	44.9	N	42.1	N	35.9	N
APR	43.1	WSW	42.8	W	41.0	W	30.1	W
MAY	52.8	SSW	48.1	SSW	47.2	NW	35.5	SSE
JUN	44.6	S	47.8	W	45.9	NNW	29.4	NW
JUL	40.2	E	37.3	SSE	40.1	SSE	23.3	NNW
AUG	45.1	NE	46.9	NNW	41.3	NNW	26.4	ESE
SEP	49.4	NNW	35.7	N	45.1	N	25.6	SSW

Table 7.5-2 Meteorological Tower Comparison of Temperature (°F)

	MAXIMUM TEMPERATURE				MINIMUM TEMPERATURE				AVERAGE TEMPERATURE			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
February 1989	30	29	29	NA	13	12	13	NA	21	20	20	NA
March	55	54	54	NA	30	29	29	NA	42	42	42	NA
April	61	63	62	NA	39	38	39	NA	50	51	51	NA
May	70	69	69	69	47	46	47	47	58	58	59	59
June	76	71	74	75	53	51	54	53	64	60	64	64
July	88	91	87	88	62	57	62	61	76	75	75	75
August	83	84	82	82	60	56	59	59	71	70	70	70
September	74	73	73	73	50	49	50	50	62	61	62	61
October	66	63	59	63	41	38	36	39	53	50	47	51
November	55	55	55	55	30	29	31	31	42	42	42	43
December	39	38	38	38	17	15	16	17	28	27	27	28
January 1990	47	46	46	46	26	25	26	27	36	35	36	36
February	42	42	42	42	23	22	23	23	33	32	32	32
March	49	47	47	48	30	28	29	29	39	38	38	38
April	59	58	57	58	38	37	38	38	48	47	47	47
May	67	67	67	67	44	43	43	43	56	55	55	55
June	85	84	85	85	58	57	58	58	72	71	71	71
July	81	80	80	80	60	59	59	59	70	69	69	69
August	83	82	82	83	59	59	59	59	71	70	70	70
September	78	77	77	77	56	54	55	55	66	65	65	65
FY90	63	62	61	62	40	39	39	40	51	50	50	50

AIR-TBL2.90

Table 7.5-3 Meteorological Tower Comparison of Precipitation (inches)

	MONTHLY TOTALS			
	Site 1	Site 2	Site 3	Site 4
FEB 1989	0.09	0.06	0.20	NA
MAR	0.30	0.03	0.06	NA
APR	0.00	0.00	0.10	NA
MAY	1.47	1.04	3.18	6.71
JUN	0.47	1.00	1.57	2.39
JUL	0.45	0.55	1.23	1.70
AUG	0.47	1.48	0.69	0.90
SEP	1.05	0.55	1.54	0.02
OCT	0.21	0.27	0.32	0.29
NOV	0.01	0.03	0.03	0.03
DEC	0.38	0.21	0.30	0.22
JAN 1990	0.29	0.23	0.26	0.32
FEB	0.12	0.13	0.20	0.11
MAR	2.18	1.06	2.68	1.97
APR	0.48	0.40	0.72	0.58
MAY	1.83	0.59	1.56	1.58
JUN	0.28	0.14	0.32	0.00
JUL	2.42	1.34	2.49	2.58
AUG	2.17	1.79	2.81	2.42
SEP	1.18	0.59	1.16	1.18
FY90 TOTAL	11.55	NA*	12.85	11.28

* Equipment problems during FY90 invalidated these data.

Average temperatures at each station were consistently within 1°F. Although Met Station 1 reported the highest daytime average maximum temperatures, Met Sites 2 and 3 generally reported the lowest nighttime average minimum temperatures. These three stations have the lowest elevations, and the temperature differences likely reflect the exposure and radiation characteristics of the sites. Drainage at night may have caused the lower nighttime temperatures at Met Sites 2 and 3.

Precipitation was variable from station to station, especially during the spring and summer months when thunderstorm and shower activity was highly variable across the Arsenal. The highest FY90 annual precipitation, 12.85 inches, was recorded at Met Station 3.

The FY90 joint frequency distributions (JFD) for each of the four stations is provided in Appendix J. Table 7.5-4 summarizes these distributions and provides the frequency of atmospheric stability categories for each site. (This is a principal parameter in air quality dispersion prediction.) Again minor differences are evident. Generally, the highest number of unstable and neutral conditions (categories A, B, C and D) and the lowest number of very stable conditions (category F) occurred at Met Site 4, most likely reflecting its higher and more exposed location. Stability categories at the other sites were fairly closely distributed, although category E occurred more frequently at Met Site 1, and category F (very stable) occurred most frequently at Met Site 3, consistent with lower wind speeds recorded at these sites.

Table 7.5-4 FY90 Frequency (%) of Atmospheric Stability Categories for Each Met Station

Stability Category	Site 1	Site 2	Site 3	Site 4
A	13.75	13.75	12.02	15.89
B	3.97	4.60	4.70	4.81
C	5.33	4.88	6.46	5.75
D	45.17	45.86	43.79	46.03
E	18.14	14.86	15.10	16.92
F	13.63	16.05	17.93	10.59

A conclusion of this evaluation is that for long-term and broad assessments, the differences between the four RMA meteorological monitoring sites are not significant. However, for short-term or day-to-day assessments such as real-time remedial activities or emergency alerts, significantly different air quality dispersion patterns could be identified at specific RMA locations under the four-tower network. This is illustrated in the following two examples.

On September 14, 1990, a day previously discussed when significantly high TSP and PM-10 levels were measured at the Arsenal due to an intense upper level inversion, predominant wind directions at the four meteorological sites for the 24-hour period were as follows:

Met 1	NW
Met 2	SSE
Met 3	SSE
Met 4	NW

On this date, dispersion impacts from a possible remediation source near Met Sites 1 and 4 would have been directly opposite from Met Sites 2 and 3. Fortunately, the four-site network allows each of these possible impacts to be evaluated appropriately.

As another very typical example, on July 29, 1990 at 1500 hours MST, there was considerable convective activity at the Arsenal. Wind directions reported at each of the four sites were as follows:

Met 1	SE
Met 2	ESE
Met 3	SW
Met 4	SSW

Again, potential downstream impacts from each of the four site locations would have been in different directions. These differences between sites are averaged over the long-term and are considerably less evident; however, for short-term or real-time evaluations, the differences are highly significant.

7.6 Atmospheric Dispersion Model

7.6.1 Model Applications

One of the objectives of the CMP is the identification of atmospheric conditions that may trigger high contamination levels and may require special precautions and mitigating actions. A related task is the development and/or application of air dispersion prediction techniques and models that use available site data and provide forecasts of potential contamination impacts. The Basin F program developed and applied such modeling techniques as an integral part of its program to provide for the health and

safety of workers and the general public. The CMP closely coordinated these operational activities and incorporated dispersion model results into previous reports as well as the present report. These techniques appear to be effective and are recommended for future remedial and air quality assessment applications. Specific models used in remedial operations and in data assessments are discussed below.

The models employed were the EPA Industrial Source Complex (ISC) Model (USEPA, 1986) and the INPUFF2 (PUFF advection) model (USEPA, 1986). These are standard and approved EPA models used for general purposes to predict air quality impacts. They are often used in environmental impact statements and in air quality permit applications. For Basin F remedial activities, they were modified to support the cleanup operations, and in particular, *to use real-time air quality data and real-time meteorological data.*

Because precise measurements of source emissions could not be determined, a unique approach was devised to use X/Q values, in conjunction with measured ambient concentrations, to predict short-term (operational) and longer-term (assessment) impacts. The X/Q values, as noted in previous discussions relating to the CMP and Basin F monitoring results, do not indicate ambient concentrations, but rather, indicate relative strength, or potential concentration levels based on meteorological conditions and on an undetermined emission source strength. In the Basin F program, the X/Q values were calibrated with real-time monitoring data to predict ambient concentrations in support of the remedial operations. Appendix K documents basic features of the EPA INPUFF2 and ISC models. In Gaussian dispersion models, the ground level concentrations of contaminants in a plume can be computed by:

$$X = \frac{Q}{\pi \sigma_y \sigma_z u} \cdot \exp\left[-1/2\left(\frac{ESH}{\sigma_z}\right)^2\right]$$

Where X = predicted ground level concentration
Q = source emissions
σ_y = horizontal dispersion coefficient (function of distance from source)
σ_z = vertical dispersion coefficient (function of distance from source)
u = mean wind speed at plume level
ESH = effective stack height, (or plume height level assumed for Basin F application)

When the source emission term is not determined, the equation can be written as follows:

$$X/Q = \frac{1}{\pi \sigma_y \sigma_z u} \cdot \exp\left[-1/2\left(\frac{ESH}{\sigma_z}\right)^2\right]$$

For the present assessment applications, assuming that Q is constant, or near constant (at any given time), the relationship between an observed (monitored) concentration at a specific grid location where a X/Q was calculated, and at another *unmonitored* location where a X/Q was also determined was the ratio between the two values. This was a very simple approach, but was highly effective in determining the spread of a dispersion plume beyond and between the monitoring networks. The technique will allow for the prediction of future concentrations during ongoing operations, assuming that emissions do not significantly change during a particular operation. As remedial progress continues and emissions are eventually reduced, observed concentrations for a specified X/Q should also be reduced. This was the case for the IRA-F data for Phase 4 provided in this report, as compared to Phase 1 results discussed in the FY88 Data Assessment Report. Thus, the model has the potential to evaluate remedial progress under comparable meteorological and air dispersion conditions.

The PUFF model was used primarily for short-term predictions at Basin F in conjunction with real-time operations. Air monitoring was conducted using HNU, OVA, ammonia and dust monitors at various remedial activity areas and along the Exclusion Zone perimeter. Perimeter readings were taken at four fixed locations and also downstream from Basin F, based on the prevailing wind, where maximum concentrations were anticipated. Concurrent with each monitoring reading, the PUFF model was run to determine the trajectory of the contamination plume. The X/Q values of the model were then immediately matched with actual monitored data to determine the potential distribution of the plume trajectory and the likelihood of Level B exceedances outside the protected areas. A maximum limit of 1 ppm was established for expansion of the Exclusion Zone and/or evacuation of personnel without protective clothing and equipment.

Both the PUFF model and the ISC model have the capability to provide longer-term X/Q dispersion assessments. Because the PUFF model operates on 15-minute trajectories, it takes much longer to run, and the ISC model was primarily employed for 24-hour assessments and beyond. However, the PUFF model can be used to assess longer-term episodes if more refined or sensitive analyses are required.

The results of the CMP and Basin F monitoring programs, discussed in Section 4, were compared with dispersion analyses obtained from the EPA Industrial Source Complex model. As noted, these evaluations provided highly useful information for associating dispersion patterns and meteorological conditions with observed and potential air contamination levels. When a distinct source was evident, such as Basin F, Basin A, or the South Plants, the model identified the spread of the dispersion plume downstream from the source. The concurrent monitored data then provided a mechanism for calibrating and projecting ambient concentrations throughout the Arsenal and beyond its boundaries. The model identified worst-case meteorological conditions and seasonal and diurnal effects, thus providing a basis for mitigation actions. For future assessments, it provides a basis for evaluating remedial progress by ensuring that monitoring results are compared to similar worst-case meteorology and seasonal conditions.

The effectiveness of model applications is evident from the data and comparisons shown in the proceeding sections. The impacts from known RMA sources, or remedial activities, have been identified and the relative strength of these impacts with distance from the source have been quantitatively determined. There is also considerable scatter of X/Q values at specific site locations, which can be attributed to many factors beyond the simplified model's present capabilities. These include variations in source emissions and remedial production activity, both of which obviously result in variations in concentration levels downwind from the source; the existence of other potential area and local sources, which present a "noise" factor in the database; short-term meteorological influences that are not integrated into the hourly Industrial Source Complex database (this suggests the special advantage in using the short-term PUFF trajectories); and the general complexity of the dispersion process that is not entirely identified in the model.

In summary, the PUFF and Industrial Source Complex models, using the X/Q calibration approach, were and will continue to be workable vehicles for projecting contamination levels during remedial activities and for assessing remedial progress. It is not the purpose of the CMP to do extensive research investigations to improve model validation and applications. Nevertheless several practical follow-on efforts may be applied in future CMP evaluations that would not only improve the models but would also provide considerable insight into the general assessment of RMA contamination levels during subsequent remedial activities. These are discussed below.

7.6.2 Additional Model Approaches and Analyses

7.6.2.1 Source Emissions Characterization

The standard dispersion model predicts ambient concentrations based upon meteorological factors and a known, or estimated, emission source. The Basin F real-time application, as well as for the CMP, have to a certain extent effectively bypassed the emissions term and substituted a mechanism (X/Q values) for providing contamination levels based upon concurrent monitoring data. More precise data on emission releases at potential RMA and off-Arsenal contamination sources will add an additional dimension to the modeling and prediction capabilities. Data indicating the combination of emission levels, meteorological factors and resultant ambient concentrations will also allow for still further refinements of the model. For subsequent cleanup activities at RMA requiring air quality impact assessments, precise emissions data and characterizations will enhance prediction capabilities.

7.6.2.2 Remedial Activity Production Data

It is evident from the Basin F monitoring results during remedial operations and from the previous Remedial Investigation Program results prior to remedial operations that the cleanup activities resulted in increases in some of the monitored pollutants, in particular TSP, pesticides, organic compounds and some metals. It may be assumed that these increases were a direct consequence of and proportional to the extent of remedial efforts on a day-to-day basis. Various information pertaining to the status and intensity of cleanup operations, including the tons of soil and sludge removed and hauled each day, the type and number of vehicles and type of equipment employed, storage areas and uncovered waste pile areas, the number of gallons of liquid transported, and any other emission-producing factors related to operations would be especially useful in assessing relative emissions potential and in refining model prediction capabilities. These data were available, to a limited extent, during the Basin F operations, but not necessarily on a real-time basis; this made it difficult to interpret the cause of higher contamination events and the extent of mitigation efforts that were needed. It should be noted that many industrial real-time air quality prediction systems are directly related to production factors (Edson, 1976, 1977, 1978), and this approach would have equally valid application for waste cleanup operations.

7.6.2.3 Local and Regional Emissions Inventory

One of the difficulties in analyzing the CMP and Basin F data was that there were obviously other local and regional air emissions sources in the RMA vicinity that contributed to air pollution levels measured at RMA monitoring sites. As noted in the data evaluations, metropolitan Denver was a source of TSP, PM-10, some metals, gaseous criteria pollutants and, undoubtedly, certain organics. Also, various industrial sources and farming areas in North Denver, Commerce City and Adams County may have contributed to organics and other potential contaminants. In this report, an attempt has been made to identify these sources in order to properly evaluate their contribution to RMA monitored data. They present an unknown (or noise) factor in the dispersion model prediction evaluations of potential RMA contamination and remedial impacts unless properly identified. Consequently, an inventory of local off-RMA sources is highly desirable for the interpretation of baseline data and remedial progress at RMA. Work has begun on this effort and an inventory of known sources is included in this report; these data contribute to the overall analyses. Additional work is also required in identifying the contributions and impacts of metropolitan mobile sources on RMA monitoring results. Quantification of such influences would again enhance model evaluations and prediction capabilities. Much of this information is available in the Colorado Department of Health files, the Air Toxics Study for Denver conducted by EPA and other reports including the Citizens Report on Toxic Pollution in Colorado (see Section 4.0).

7.6.2.4 Empirical/Statistical Adjustments

A final approach for model improvement is the application of empirical techniques and pertinent, or unique, physical relationships to improve model capabilities. As examples, it is generally agreed that organics are released into the atmosphere at warmer temperatures and also under certain favorable air pressure conditions; TSP, metals, and PM-10 are generally higher after certain threshold wind gust levels are achieved. Also, very localized, topographic site-specific characteristics may be evident in the spread of potential air contaminants over the area which are not considered in the dispersion model. The database now being collected provides a mechanism for establishing some of these influences; some have already been identified in the present report. It is anticipated that this effort will continue, and if possible, validated relationships will be incorporated into model applications.

8.0 QUALITY ASSURANCE PROGRAM

8.1 Overview and General Guidance

The CMP Quality Assurance Program for Air Monitoring was designed to assure that the data generated were accurate, precise, and met the requirements of the project and needs of the data user. Most of the monitoring and analytical techniques used were certified by PMRMA. Noncertified methods had USEPA approval. Each method has its own prescribed quality control and quality assurance procedures which is in accordance with the Chemical Quality Assurance Plan (PMRMA, 1989). The basic guidelines for developing monitoring methods and procedures are described in the following documents:

- "CMP Field Procedures Manual";
- "PMRMA Certified Analytical Methods";
- "Ambient Monitoring Guidelines for Prevention of Significant Deterioration," EPA-450/4-87-007;
- "Ambient Air Quality Monitoring, Data Reporting, and Surveillance Provisions," 40 Code of Federal Regulations, Parts 51, 52, 53 and 58;
- "Quality Assurance Handbook for Air Pollution Measurement Systems," Volumes I, II and IV, EPA-600/9-76-005, EPA-600/4-77-027a, and EPA-600/4-82-060; and
- "Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air," EPA-600/4-84-041 and updates.
- Chemical Quality Assurance Plan, Version 1.0, July, 1989.

Under PMRMA definitions, quality assurance is the total integrated program for assuring and documenting the reliability of monitoring and measurement data and for integrating quality planning, quality assessment and quality improvement efforts to meet user requirements. Integrated into the QA plan is quality control (QC) which is the routine application of procedures for obtaining

prescribed performance standards in the monitoring and measurement process. Examples of QCs are field and trip blanks, laboratory spikes and duplicates.

For the purposes of the CMP Air Monitoring Program, quality control using project guidelines were those procedures that were routinely followed during the normal operation of the monitoring system. These included periodic field "spikes" and field blank sample analysis, collocated sample analysis, calibration of field and laboratory equipment, preventive maintenance, site inspections, and routine data screening and validation checks. Quality assurance (or quality assessment) were those procedures performed on a routine but less frequent basis to validate the data generation process. These assurance procedures were performed by a person not involved with the corresponding day-to-day project activities. Quality assurance procedures included system and performance audits, standard intercomparisons, crosschecking of reported data values against original raw data records and data from other similar locations, and periodic evaluation of internal quality control data. The objectives of the quality control and quality assurance procedures were to produce data that met RMA requirements measured in terms of precision, accuracy, representativeness, comparability, and completeness.

The remainder of this section is divided into the following subsections: a brief overview of the laboratory quality assurance and quality control program, a description of the field quality control results, a description of the field quality assurance results and a description of quality assurance associated with data processing. More detailed discussions are provided in the CMP Field Procedures Manual (Stollar, 1988).

8.2 Laboratory Quality Control and Quality Assurance Program Overview

The laboratory quality assurance and quality control program was extremely rigorous and was based on PMRMA certification procedures. These procedures assured the accuracy and integrity of the collected database through a control chart process. The certification program consisted first of rigorous precertification and certification procedures of the analytical methodologies that were satisfactorily completed before sampling and data collection. Second, prescribed routine quality control and quality assurance procedures were followed during the sampling program to ensure that the entire sampling method was performing comparable to the level demonstrated during certification.

The laboratory certification procedures consisted of determining several key parameters. Extraction or desorption efficiencies were determined by spiking the sample media with known amounts of the

target analytes and performing the analyses along the analytical guidelines. A percent recovery for each of the compounds was determined from multiple spiking tests. Accuracy adjustments were determined from the mean of the percent recoveries at certification. One and two standard deviations from the mean of the recovery data was used to validate the subsequent data giving a 95 percent confidence level to the data. A range of concentrations was used to test the linearity of the laboratory instrument response and to certify an analytical range for each target analyte, with values denoted as the upper and lower certified reporting limits.

Reporting ranges were determined at the time of certification. Values found below this range were reported as "less than" the lower reporting limit. Values found above this range were reported as "greater than" (GT), and were then estimated. These values are considered qualitative, and are used as a "best guess" of concentration ranges. Upper limits did not apply to TSP and PM-10 measurements. For SVOCs and metals analysis, extract solutions were diluted (if possible) for reanalysis if the initial readings were above the certified range and holding times for the extracts had not yet expired.

The VOC laboratory analysis technique differed significantly from other techniques because there was no possibility of diluting or reanalyzing samples. The VOC Tenax sorption tube was placed into a heating block connected to the inlet of the analytical instrument. This block or thermal desorber was quickly heated to desorb all the volatile compounds off of the Tenax. A small air flow was passed through the tube simultaneously, which allowed these compounds to be quickly injected into the analytical instrument through a heated stainless-steel interface. Therefore, this method was a "one shot" technique, and if the sample concentration was outside certified limits, there was no way to dilute and reanalyze the sample. In the FY90 program, there were instances where a sample had collected an amount above the certified range for some compounds. An assessment of the concentration was made by using the hypothesized concentration curve above the certified range. Such results represented the best estimate of the observed concentrations; however, these data were not certified in accordance with PMRMA standards and were likely to represent a low estimate of actual concentrations.

The above measures of laboratory accuracies, certified ranges, and extraction efficiencies were directly incorporated into the database processing system that was used to report air quality data. This system is the Installation Restoration Data Management System (IRDMS). In IRDMS, the raw laboratory results are sent to Ebasco, the data are checked for errors, adjusted for flow volumes, and sent to DP Associates and held in the QC holding database. Once the Army has accepted the data as

meeting the QA criteria, it is then corrected for accuracy and loaded into the official database. Data outside of certified ranges and rejected under the QA criteria are placed in a rejected data file for informational use only. The resulting product is a high-quality analytical database that was available to field personnel for calculating ambient concentration data.

8.3 FIELD QUALITY CONTROL PROGRAM

8.3.1 ORGANIZATION

The field monitoring team was organized to conduct several activities that provided data quality control for the program. At the outset, a monitoring team supervisor was designated and a set of procedures was drawn up to address quality control. The field supervisor and project manager insured that the quality control procedures were implemented.

Standard field data sheets were used by the project team. Each team member was trained in the use and entry of data on this form. Forms were documented in project files, and copies were distributed to the project manager for periodic review. Calibration data sheets were also drawn up for the project and the calibration team was trained in their use. The field and calibration data sheets were stored on-site and a copy was sent to the project manager. The field supervisor was responsible for ensuring that these records were maintained, routinely reviewed and updated, and used by the data processing personnel. Final deposition of these documents are the project files and will ultimately be sent to PMRMA at project close-out.

8.3.2 FIELD PROGRAM QUALITY CONTROL

For each of the sampling techniques used, the air quality technical plan specifies target flow rates and sampling durations. These values were used during the field sampling activities and were documented by periodic equipment calibrations as well as checks during each sampling event. Quality assurance limits were set up using the EPA Quality Assurance Handbooks for acceptable instrument performance. Whenever a flow rate or elapsed timer was outside of acceptable limits, corrective maintenance was performed to bring the defective component or activity back into tolerance. The activities were documented and kept with field file records.

The high-volume field equipment used to sample TSP, PM-10 and metals was electronically flow-controlled to maintain a constant flow rate. A certified flow measuring orifice was routinely used

to calibrate the flow rate set point. Calibrations were performed once per quarter or more frequently if needed. For the SVOC and OCP high-volume samplers, a flow rate gauge was used to monitor the flow rate of the sampler. During calibration of these samplers, a range of flow rates was measured with the orifice, and a linear regression was developed relating the sample indicator reading to the orifice flow rate. The maximum deviation of any flow rate point from the linearly interpolated value should be less than 7 percent for the TSP, PM-10, SVOC, and OCP samplers. For TSP and PM-10, visual inspection of the Dixon chart indicated whether the flow deviated during the sampling period.

The low-volume field sampling equipment, which measured VOCs, mercury and ammonia, were Gilian constant flow sampling pumps equipped with rotameters. Before each field sampling event the pumps were calibrated and set to specific flow rates as determined by a certified mass flowmeter. During a sampling event, personnel routinely inspected the rotameter to ensure correct flow rate readings.

8.3.3 Quality Control Field Sample Results

8.3.3.1 VOC Quality Control Results

The specified requirement for determining efficiency of the sampling equipment is to compare the volume of air sampled to establish acceptable sampling volumes. The Tenax collector for VOC sampling will not capture all of a particular compound greater than a specified sample volume. The sampling volume should not exceed the established "breakthrough" volume for the compound of interest in relation to the amount of sampling matrix (i.e., Tenax).

The sampling media employed consists of a front sorbent tube containing Tenax and a second or backup tube containing Tenax and charcoal. The tubes were analyzed simultaneously, therefore, actual "breakthrough" was not assessed. Theoretical "breakthrough" volumes were calculated based on the amount of Tenax contained in the tubes.

The standard VOC method prescribes the use of collocated samples as a quality assurance procedure that can be used to increase confidence in the data that are generated. This technique has been used by the CMP and results are discussed in Section 8.4. The recommended performance criteria is that the mean difference between the pairs of collocated samples should generally be within 25 percent of the sample mean.

Field blank values were also compared to field sample analytical values. As stated in the VOC method, the blank sorbent trap should contain less than 10 ng of the target compounds before it is sent to the field. Table 8.3-1 presents a summary of the target VOC blank values for all of the field and trip blanks during FY90. For most of the target compounds, field blank levels were less than the certified reporting limit (which generally corresponds to approximately 10 ng per sample). However, some field blanks showed detectable levels of benzene, methylene chloride, and 1,1,1-trichloroethane (111TCE). Benzene was detected in all field blanks except one, and five samples had methylene chloride levels above the certified reporting limit. The level of 111TCE detected was near the lower certified reporting limit. Therefore, because blank correction was not performed during the CMP on VOC data, the benzene and methylene chloride data especially should be considered conservative, and the actual ambient concentrations may be lower than presented in this report. Detections of benzene in the blanks can be explained by Walling et al. (1986), who observed a decomposition product of benzene when Tenax was repeatedly heated to 200°C. The other two are common laboratory solvents and are easily retained on Tenax.

8.3.3.2 Semi-Volatile Organics and Organics on PUF Quality Control Results

Quality control samples for semi-volatile organic compounds and organochlorine pesticides consisted of field blanks, trip blanks and aerated field spikes. The SVOC and OCP sampling methods were identical; both consisted of a polyurethane foam sorbent plug and quartz filter used in a high-volume sampler. In the SVOC analytical method, gas chromatograph/mass spectrometer (GC/MS), was used for detection. This analytical device has the ability to measure a wide variety of compounds, other than the target analytes, yet has a moderately high detection limit. For OCP samples, a gas chromatograph/electron capture detector (GC/ECD) was used. This device analyzed only the organochlorine pesticides for which it was certified and had a very low detection limit. All organochlorine pesticides, with the exception of aldrin, were included in the SVOC target list. The aldrin concentrations reported for the OCP technique must be used with caution. In actual field sampling there is the potential for stripping or oxidation of aldrin, and the recovery of spiked aldrin samples is known to be low (USEPA, 1984).

Two field spiking events were performed for CMP's 1990 Air Monitoring program. The results for the first (SVOC) effort are listed in Table 8.3-2. The spiking solution was prepared by the ESE/Denver laboratory and sent to the field team.

Table 8.3-1 CMP Target Volatile Organic Compounds (VOC) Blank Values (in µg)

Tag #	111TCE	112TCE	11DCLE	12DCLE	BCHPD	C6H6	CCL4	CH2CL2	CHCL3	CLC6H5	DBCP
24579 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.029 LT	0.013 LT	0.008 LT	0.006 LT	0.0095 LT	0.011
24621 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.039 LT	0.013 GT	0.200 LT	0.006 LT	0.0095 LT	0.011
24659 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012 LT	0.007 LT	0.013 LT	0.008 LT	0.006 LT	0.0095 LT	0.011
24680 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.008 LT	0.013 LT	0.008 LT	0.006 LT	0.0095 LT	0.011
24690 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.032 LT	0.013 LT	0.008 LT	0.006 LT	0.0095 LT	0.011
24700 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.015 LT	0.013	0.060 LT	0.006 LT	0.0095 LT	0.011
24721 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.007 LT	0.013	0.051 LT	0.006 LT	0.0095 LT	0.011
24731 LT	0.0175 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.020 LT	0.013	0.066 LT	0.006 LT	0.0095 LT	0.011
24741	0.0490 LT	0.0085 LT	0.007 LT	0.006 LT	0.012	0.039 LT	0.013	0.073 LT	0.006 LT	0.0095 LT	0.011
MAX	0.0490	0.0085	0.007	0.006	0.012	0.039	0.013	0.200	0.006	0.0095	0.011
MIN	0.0175	0.0085	0.007	0.006	0.012	0.007	0.013	0.008	0.006	0.0095	0.011
AVG	0.0210	0.0085	0.007	0.006	0.012	0.022	0.013	0.054	0.066	0.0095	0.011

LEGEND:

111TCE	1,1,1-Trichloroethane
112TCE	1,1,2-Trichloroethane
11DCLE	1,1-Dichloroethane
12DCLE	1,2-Dichloroethane
BCHPD	Bicycloheptadiene
C6H6	Benzene
CCL4	Carbon Tetrachloride
CH2CL2	Methylene Chloride
CLC6H5	Chlorobenzene
CHCL3	Chloroform
DBCP	Dibromochloropropane

Table 8.3-1 CMP Target Volatile Organic Compounds (VOC) Blank Values (in μg) (continued)

Tag #	DCPD	DMDS	ETC6H5	MEC6H5	MIBK	NNDMEA	12DMB	T12DCE	TCLEE	TRCLE	XYLENE
24579 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24621 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24659 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24680 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24690 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24700 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24721 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24731 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
24741 LT	0.013 LT	0.0135 LT	0.0085 LT	0.023 LT	0.005 LT	0.0295 LT	0.008 LT	0.115 LT	0.0095 LT	0.015 LT	0.0405
MAX	0.013	0.0135	0.0085	0.023	0.005	0.0295	0.008	0.0115	0.0095	0.015	0.0405
MIN	0.013	0.0135	0.0085	0.023	0.005	0.0295	0.008	0.0115	0.0095	0.015	0.0405
AVG	0.013	0.0135	0.0085	0.023	0.005	0.0295	0.008	0.0115	0.0095	0.015	0.0405

LEGEND:

DCPD	Dicyclopentadiene
DMDS	Dimethyl Disulfide
ETC6H5	Ethylbenzene
MEC6H5	Toluene
MIBK	Methyl Isobutyl Ketone
NNDMEA	N-Nitrosodimethylamine
12DMB	Dimethylbenzene
T12DCE	Trans-1,2-Dichloroethene
TCLEE	Tetrachloroethene
TRCLE	Trichloroethene
XYLENE	Xylene

Table 8.3-2 Summary of Semi-Volatile Organic Compounds Results of Field Spiking

Target Analyte	Control Conc. (μg)	% of Recovery #1	% of Recovery #2
Aldrin	LT*	LT	LT
Atrazine	LT	39	32
Chlordane	LT	110	102
CPMS	LT	LT	LT
CPMSO	LT	42	93
CPMSO2	LT	65	81
DBCP	LT	LT	LT
DCPD	LT	LT	LT
DDVP	LT	LT	LT
DIMP	LT	LT	LT
DITH	LT	LT	LT
Dieldrin	LT	149	129
DMMP	LT	LT	LT
Endrin	LT	160	138
HCBD	LT	LT	LT
Isodrin	LT	LT	LT
Malathion	LT	80	61
Oxathiane	LT	LT	LT
PPDDE	LT	150	123
PPDDT	LT	135	125
Parathion	LT	103	81
Supona	LT	153	91

Note: 45 μg were spiked onto 2 separate PUFS.

* LT refers to detections less than the lower certified reporting limit. Recoveries are generally less than 10%.

The second, OCP, field spike occurred on August 14, 1990. A solution containing all OCP target analytes was spiked at 1.25 μg directly to the PUF. The spike was duplicated on a second PUF set in close proximity to the first station. Another PUF also set-up in the same vicinity was not spiked for use as the control sample. Table 8.3-3 provides the percent recoveries from the in-field OCP spike event.

Table 8.3-3 Summary of OCP Results of Field Spiking

Target Analyte	Control Sample	Percent Recovery #1	Percent Recovery #2
Aldrin	LT	LT	LT
Chlordane	.227	82	78
Dieldrin	LT	106	98
Endrin	LT	114	104
Isodrin	LT	LT	LT
PPDDE	LT	96	97
PPDDT	LT	132	113

* LT refers to detections below the lower certified reporting limit. Recoveries are generally less than 10%.

Aldrin and isodrin were not detected at 0.1 μg and appeared to be lost during the aeration process. Analytical results for these two compounds must be interpreted in light of the low recoveries. All the other analytes showed consistent, good recoveries, proving that the method employed does, indeed, collect and retain these contaminants of concern.

SVOC and OCP collocated samples had good correlation. Accuracy for OCPs was between 90 and 120 percent recovery. Accuracy for SVOCs fluctuated more because the method is semi-quantitative, but values were within acceptable criteria. The SVOC and OCP field blanks results indicate that all field blanks for all target SVOCs and OCPs were below the lower certified reporting limit.

8.3.4 Data Processing

A series of formal steps was implemented to ensure the quality of data generated under this program. For all analytes the laboratory determined the raw target weight for each sample; the IRDMS adjusted this weight by a method accuracy correction; the monitoring team calculated a volume associated with

each sample; and the adjusted weight was divided by the sample volume to obtain a concentration per unit volume of air sampled.

The quality assurance group reviewed the laboratory quality control data, including surrogate and spiked recoveries and general compliance with the PMRMA quality control methodology. The acceptability of each lot was addressed by the laboratory and was reviewed for approval by the quality assurance team. The control charts were reviewed to indicate method control and submitted to PMRMA. The laboratory provided a paper copy and a diskette of uncorrected sample weights to the data management group. The printout of diskette data was compared with the papercopy results and any discrepancies were resolved. For each target compound in each group of data, a check was made of at least one sample to assess the method accuracy correction.

The field team generated a sample volume computation on spreadsheet software using the field calibration, flow check and timing data. Spreadsheet entries were checked and volume computations were verified by the quality assurance group. The data processing group generated sample concentrations from the weight and volume data. A series of group checks and record checks verified the conduct of the quality control effort, holding times, and that data were within certified limits. Finally, the quality assurance program provided documentation that the database was generated in accordance with quality assurance procedures.

8.4 Assessment of Data Precision and Collocated Duplicate Sampling Results

The CMP collocated sampling effort was performed at Site AQ5, and the pairs of samplers were located approximately 3 meters from one another. Results were calculated for all target compounds and detailed data are presented in Appendix H. Collocated sample comparisons are listed in Table 8.4-1. Only the sample pairs with results above the lower certified reporting limit (LCRL) were used to compare collocated results. The average percent difference is the mean difference as a percent of the mean collocated sample concentrations. For TSP, PM-10, and metals a pair of collocated samples was taken for every collection date set at every 6 days and for every high event episode; therefore, 65 sets of comparable data for collocated metals samples exist for the 1990 monitoring year under CMP. For TSP and PM-10 the ±95 percent confidence intervals were computed and expressed as a percent of sample mean. For TSP, these intervals range from -10.2 percent to 8.0 percent. For PM-10, the range is -23.3 percent to 18.3 percent.

Table 8.4-1 Collocated Sample Comparisons for FY90 at AQ5

Target	# Pairs	# >LCRL*	Average Percent Difference
TSP	55	49	-1.5
PM-10	56	20	-3.5
Cadmium	65	6	-10.3
Chromium	65	0	
Copper	65	65	35.8
Lead	65	31	0.5
Zinc	65	61	8.5
Arsenic	65	6	-24.9
VOC **			
1,1,1-Trichloroethane	10	10	1.6
1,1,2-Trichloroethane	10	0	
1,1-Dichloroethane	10	0	
1,2-Dichloroethane	10	5	11.4
Bicycloheptadiene	10	0	
Benzene	10	10	13.0
Carbon Tetrachloride	10	10	-3.8
Methylene Chloride	10	10	-27.8
Chloroform	10	8	-14.1
Chlorobenzene	10	0	
Dibromochloropropane	10	0	
Dicyclopentadiene	10	0	
Dimethyl Disulfide	10	0	
Ethylbenzene	10	10	21.7
Toluene	10	10	-3.0
Methyl Isobutyl Ketone	10	4	11.6
N-Nitrosodimethylamine	10	0	
Dimethylbenzene	10	10	-3.8
Trans-1,2-Dichloroethane	10	0	
Tetrachloroethene	10	10	13.9
Trichloroethene	10	3	-23.4
Xylene	10	10	25.7
OCP			
44DCBZ(S)	7	7	3.9
Aldrin	9	0	
Chlordane	9	1	-20.7
Dieldrin	9	0	
Endrin	9	0	
Isodrin	9	0	
PPDDE	9	0	
PPDDT	9	0	

Table 8.4-1 Collocated Sample Comparisons for FY90 at AQ5 (continued)

Target	# Pairs	# >LCRL*	Average Percent Difference
SVOC (Methods F7, CM02, and CM03)			
Atrazine	6	0	
Chlordane	6	0	
D4-1,3-Dichlorobenzene(S)	6	20.33	
D4-2-Chlorophenyl(S)	6	22.25	
Chlorophenyl methylsulfoxide	6	0	
Chlorophenyl methylsulfone	6	0	
D-4-Diethylphthalate(S)	6	12.08	
Dieldrin	6	0	
D4-Dioctylphthalate(S)	6	4.34	
Endrin	6	0	
Isodrin	6	0	
Malathion	6	0	
PPDDE	6	0	
PPDDT	6	0	
Parathion	6	0	
Supona	6	0	
SVOC (Method CM03)			
2FBP(S)	5	5	-8.43
Aldrin	5	0	
CPMS	5	0	
DBCP	5	0	
DCPP	5	0	
DDVP	5	0	
DIMP	5	0	
DITH	5	0	
DMMP	5	0	
HCBD	5	0	
NBD5(S)	5	5	-11.96
OXAT	5	0	
TERD14(S)	5	5	-14.71

* For TSP and PM-10, below LCRL refers not to LCRL, but 20 $\mu g/m^3$.

** For VOCs, precision calculations were based on all observations both above and within certified reporting limits.

(S) Surrogate

Legend: PPDDE = Dichlorodiphenyldichloroethylene
PPDDT = Dichlorodiphenyltrichloroethane

The percent differences were calculated by dividing the difference between the pair by their average. Percent differences were calculated for positive target analyte values that were PMRMA validated. Most of the comparisons consistently fell within ±50 percent difference. A few outliers existed for zinc and copper, which are known contaminants within the glass fiber filter employed by MRI laboratory and the quartz filter employed by ESE laboratory. One outlier existed for arsenic during the November 6, 1990 sampling event.

Generally, the values obtained in comparing collocated samples were within acceptable limits, indicating that the method was stable and provided comparable results.

For TSP and PM-10, the 95 percent confidence limits were calculated on the basis of standard statistical techniques for normal distributions. These values represent, with 95 percent confidence, the limits between which the actual median value lies. The observed 95 percent confidence limits for total suspended particulates and inhalable particulates all fell within the ±25 percent guideline. The 95 percent confidence limits for lead fell within ±30 percent precision range.

Collocated samples for volatile analysis are also listed in Table 8.4-1. These samples were collected on high event days as described in Section 4.6. There were 10 sets of collocated samples for the 1990 CMP Air Monitoring year. All samples were collected at Site AQ5 except for the samples collected on September 11, 1990 at Site AQ10. Sampling units were spaced in close proximity at approximately 3 ft apart.

Comparisons between the collocated samples are expressed as an average percent difference of all collocated samples. The volatile sample comparisons are unique in that many of the target compound detections are values above the linear certified range for the method employed. These concentrations are estimated values based on the upper non-linear portion of the calibration curve and provide conservative "best guess" values. Percent differences on these values are allowed more deviation since the 95 percent confidence limits on the values do not apply. Despite the possible error involved, the actual percent differences exhibit good stability within ±50 percent. One set of data for methylene chloride (CH2CL2) on the September 11 sampling day differs by 100 percent and is altogether possible given the estimation error and the fact that CH2CL2 is also a common laboratory contaminant. Other values differing by greater than 100 percent are for toluene and 1,2-dimethylbenzene and are possible outliers despite the error factors. The method exhibits stability for values within the certified reporting limit. Overall, the values are comparable indicating representative sampling conditions.

The semi-volatile collocated samples listed in Table 8.4-1 were collected during high event sampling (described in Section 4.7) and were therefore assembled at different site locations. The sampling units were placed approximately 3 ft apart and were set for the same sampling rate. Six collocated sets were taken for the 1990 monitoring year. Comparisons were made using percent differences. No target analytes were detected above the lower certified limit and were depicted as less than the CRL.

Surrogate comparisons can be used to assess method stability and extraction efficiency but not representativeness of the sampling method. MRI laboratory reported one set of surrogate recoveries for comparison. The percent differences for the four surrogates ranged from 4 to 22 percent. ESE reported five collocated sample sets. The average percent differences for the three surrogates were less than 15 percent. Most of the actual percent differences ranged from 3 to 30 percent with one possible outlier at 51 percent difference. Variability among surrogates was within acceptable ranges. Therefore, method stability indicates control and extraction efficiency was acceptable.

Collocated samples for organochlorine pesticides in air were collected at sites AQ5E and AQ5F. The sampling units were placed approximately 3 ft apart and were set for the same sampling rate. Nine collocated sample sets were taken for the 1990 monitoring year and were scheduled for monthly collection. Some data points are missing due to breakage during shipping or laboratory error. PMRMA validated, useable data are shown in Table 8.4-1. Comparisons were made using the percent difference between collocated #1 and collocated #2 samples. These calculations were performed by dividing the difference of the pair by their average. Only one set of collocated samples detected concentrations (in $\mu g/m^3$) within the certified reporting limit (CRL). All other reported values were less than the CRL.

Chlordane was found near detection levels for Sites AQ5E and AQ5F on August 21, 1990. Their percent difference was 20.68 and is within the acceptable criteria of ±35 percent. (Although no guidelines on comparing collocated OCP samples in air are available, a nominal ±35 percent is used because of variabilities inherent on the sample matrix and adsorbent. A ±35 value is also used to compare duplicates in soil for the Inorganic CLP Program.) Values near the CRL, 10^{-5} $\mu g/m^3$, are approaching the outer limits of the 95 percent confidence levels producing larger fluctuations in the percent difference than if concentrations were at mid-range of CRLs.

Since there were few detections of target analytes in the collocated samples, the precision of the surrogate gives an indication of method control. The values of the surrogate, 4,4-dichlorobenzophenone (44DCBZ) are included in Table 8.4-1 to provide information on method

stability and extraction efficiency. 44DCBZ is spiked at a known concentration into each sample before the extraction process. 44DCBZ is similar to the compounds of interest and was chosen since it is not normally found in nature nor used in most chemical processes. The method exhibited stable behavior between samples, with percent differences of <10 percent. Surrogate recoveries are not certified and were, therefore, not reported from all laboratories.

The continuous monitoring stations analyzed for ozone, carbon monoxide, sulfur dioxide and nitrogen oxides. Precision checks were performed on the individual analyzers at least two times per month. These checks entailed analyzing an amount of calibration/standard gas of known concentration. The response of the calibrator and analyzer were recorded as seen in Table 8.4-2 and in Appendix H. The percent difference was calculated indicating whether the instrumentation required corrective maintenance. Average percent differences were consistently 5 percent or less. Actual percent differences were also less than 10 percent except for October 13 and 23, November 8, and December 4. Stability of the analyzers is evident giving reasonable confidence for results observed.

Table 8.4-2 Continuous Air Quality Parameters Precision Results

Parameter	Average Percent Difference
Ozone	3.36
Carbon Monoxide	-5.38
Sulfur Dioxide	-3.61
Nitrogen Oxides	-5.12

8.5 QUALITY ASSURANCE FIELD PROCEDURES

CMP air monitoring quality assurance procedures included system quality assurance audits, performance audits of sampling equipment, and comparisons of calibration standards to other reference standards.

8.5.1 System Audits

System audits are the external inspection and review of monitoring operation and documentation. System quality assurance audits of the air sampling program for CMP were conducted by the project quality assurance coordinator. Operations that were audited included sample handling and use of sample containers or collectors, and documentation. Results were reported to project management with recommendations for long-term solutions and resolutions to immediate corrective actions. These reports are contained within the project files.

8.5.2 Performance Audits of Field Sampling Equipment

Performance audits were performed by personnel independent of the project. The audits consisted of testing the calibration of samplers with calibration standards other than those used to assess daily operation of the samplers.

An independent performance audit was performed quarterly on all field samplers. Detailed results of the audits can be found in the CMP Quarterly Audit Reports. Summary tables for each audit report are provided in Appendix H. For each sampler, the operator-determined flow rate was compared to the auditor flow rate and a percent difference was calculated. The results were compared to EPA guidelines of ±7 percent for an acceptable audit result. Field personnel were informed of any discrepancy and performed the required corrective action for this audit. Corrective actions were taken immediately and entered in the daily logbook.

EPA guidelines were employed to summarize overall accuracy among the network of samplers. Calculation procedures are detailed in the Federal Register, Vol. 51, #53, March 19, 1986. The procedures call for calculating the average percent difference, standard deviation, and ±95 percent confidence limits for all audit points for any particular type of sampler in the monitoring network. Three types of samplers were examined, including TSP samplers, PM-10 samplers, and the SVOC/OCP samplers. For each type of sampler, the number of audits performed were recorded along with the average percent difference and the ±95 percent confidence limits. These were compared to EPA recommended probability limits of ±20 percent for satisfactory accuracy. Results can be found in the CMP Quarterly Audit Reports, with summary tables in Appendix H.

8.5.3 CALIBRATION AND CERTIFICATION OF STANDARDS

The accuracy of flow calibration equipment was critically important for the type of monitoring performed in the CMP. Flow rate standards were calibrated against NBS traceable or other authoritative standards. Appropriate calibration intervals are yearly for the high-volume orifices and 3 to 6 months for the mass flow meter low-volume standards. The high-volume orifices and mass flow meter standards used in the CMP network were certified and compared to standards contained in the USEPA Region VIII Quality Assurance laboratory.

9.0 CONCLUSIONS

This report focuses on results of the CMP for FY90 and includes analyses and comparisons to data for preceding monitoring programs at RMA and for other programs which ran concurrently. The data were used to characterize the air quality at RMA and also to describe both the impacts of Basin F remedial activities and the cessation of those activities.

Analyses of these data were used to characterize potential sources for air contaminants which were observed, including both RMA and metropolitan Denver influences. On-site meteorological data were also used to describe those conditions associated with the average and the extreme events. Dispersion modeling was used to evaluate potential sources.

The FY90 program continued the monitoring for similar compounds which were sampled during the FY88 and FY89 programs. These include total suspended particulates, PM-10, asbestos, volatile organic compounds, semi-volatile organic compounds, organochlorine pesticides, mercury, arsenic, and other metals. The following discussion summarizes the results of the analyses for each group of air quality parameters.

9.1 TOTAL SUSPENDED PARTICULATES

TSP levels at RMA can be attributed to two principal sources: (1) the influx of particulates from metropolitan Denver, and (2) remedial activity sources which helped to produce wind-blown dust, particularly during very dry episodes. Intense remedial activity was initiated during FY88 and continued into FY89. These activities were concluded in several steps, including the completion of intrusive activities (December 12), the completion of the development of the clay caps (February 15), and the completion of all topsoil remediation activities (May 5). The TSP data clearly reflect the impact of these activities, with dramatic decreases in TSP levels around Basin F and throughout the Arsenal after the conclusion of remedial activities and in FY90. During the height of the Basin F activities, the TSP levels which could be attributed to remediation activities also decreased significantly with distance from the basin or activity source. This feature was observed in the FY88 through FY90 data with respect to Basin F activities and other localized remediation work. In addition, there were several episodes during which impacts from metropolitan Denver completely overwhelmed impacts from potential on-site sources. At the eastern and northern boundaries of RMA, the TSP levels were well below those of metropolitan Denver, and were more representative of rural conditions.

9.2 RESPIRABLE PARTICULATES (PM-10)

Respirable particulates are generated by dry windy conditions, but to a much lesser extent than for TSP. There were no violations of the annual or 24-hour PM-10 standards at RMA during FY90. There were some increases in PM-10 levels immediately adjacent to remediation activities; however, these impacts were highly localized and concentrations decreased significantly at short distances from the potential source.

9.3 METALS

Ambient concentrations of metals across RMA were generally proportional to levels of TSP. Maximum concentrations were sampled on high wind speed days and also when there were high TSP and PM-10 levels, which in turn were frequently attributed to sources off the Arsenal. During remediation activities, Basin F appeared to be a source of mercury, chromium, copper and zinc, and these concentrations decreased rapidly with distance from Basin F. Following remediation of the basin, the metals levels were reduced to those typical of baseline conditions. During FY89, there were several instances of high metals concentrations associated with low wind speeds and strong inversion conditions, with a likely source in the Denver metropolitan area.

9.4 ASBESTOS

Asbestos was not detected at RMA during FY90. There were no detections of asbestos during FY88, and only 2 days with detections during FY89; results confirm that there is no evident source of ambient asbestos fibers on RMA.

9.5 VOLATILE ORGANIC COMPOUNDS

During the Basin F remediation, on-site activities appeared to be a source of several volatile organic compounds, including bicycloheptadiene, dimethyl disulfide, benzene, toluene, and ethylbenzene. Some of these emissions could have resulted from the emissions from heavy equipment which was used during remediation. Chloroform was identified near both Basin F and the South Plants. Levels of VOCs which were attributed to RMA sources during the Basin F remediation period decreased rapidly with distance from those sources, and levels at RMA boundaries were similar to or less than those within the urban environment of metropolitan Denver. During FY89 and FY90, many of the

VOCs attributed to Basin F decreased significantly. During FY90, many of the VOCs measured at RMA monitoring sites were attributed to close-by off-Arsenal sources, as identified in this report.

9.6 SEMI-VOLATILE ORGANIC COMPOUNDS

Basin F appeared to be a source of several semi-volatile organic compounds, including aldrin, dieldrin, and endrin during the Basin F remediation activity period. The highest levels were detected in the immediate vicinity of Basin F during these remediation efforts. Results from BF2, at the northeast perimeter of Basin F, showed the highest levels of SVOCs, but at the RMA boundaries, these levels were reduced to roughly background levels. During the FY89 and FY90 post-remedial periods, SVOC concentrations were reduced significantly in the vicinity of Basin F and all SVOC concentrations at other RMA (CMP) monitoring sites were close to background levels.

9.7 ORGANOCHLORINE PESTICIDES

These compounds were at or near the detection limit at the RMA boundary sites. Highest levels were sampled during the Basin F remediation effort, and nearest to Basin F itself. Following the completion of the remedial activities, these levels were reduced to near background levels in the vicinity of Basin F as well.

9.8 CRITERIA POLLUTANTS

Ambient concentrations of the criteria pollutants, including sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone were monitored continuously at RMA during FY90. Generally, the air quality at the RMA monitoring location was cleaner than at other sites in the Denver area. The RMA data showed no violations of any short-term or long-term standards for these pollutants. Episodes with relatively high concentrations at RMA were related to potential nearby sources under certain meteorological conditions. Several of these have been specifically related to typical Denver "brown cloud" conditions and have been identified in this report.

9.9 GENERAL INTERPRETATIONS

All data reported in this report must be interpreted and used with full regard to the parameters of the program. These include sampling frequency, analysis limitations, and a limited observation period. The interpretations must also consider any anomalous meteorological (air quality) conditions as well

as possible influences of metropolitan Denver sources on RMA ambient air quality. As more data are collected under subsequent programs, these conclusions may need to be refined and reinterpreted.

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